The Journal of Bone and Joint Surgery

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The American Orthopaedic Association
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The American Academy of Orthopaedic Surgeons
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The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
South African Orthopaedic Association

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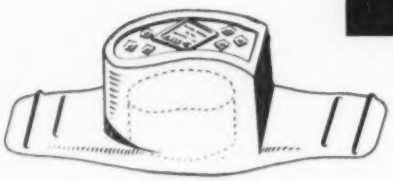

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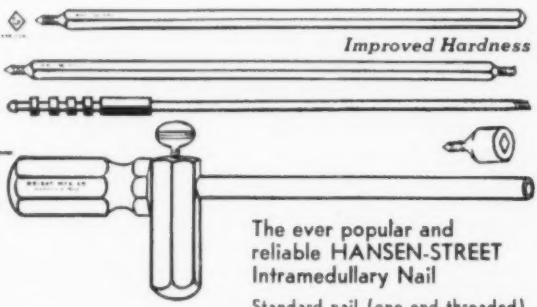

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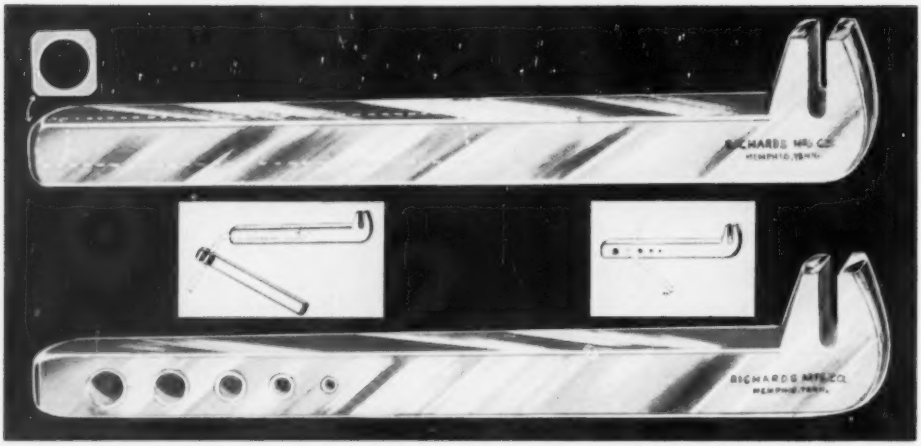

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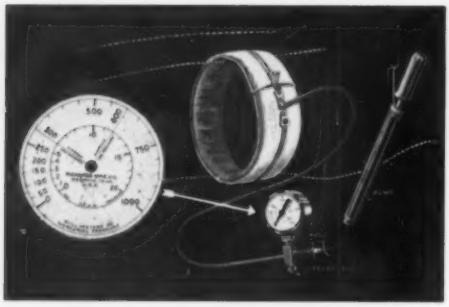

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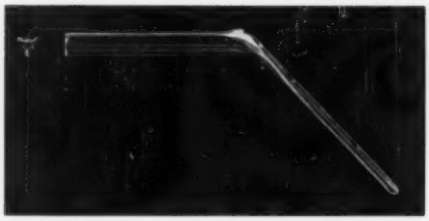

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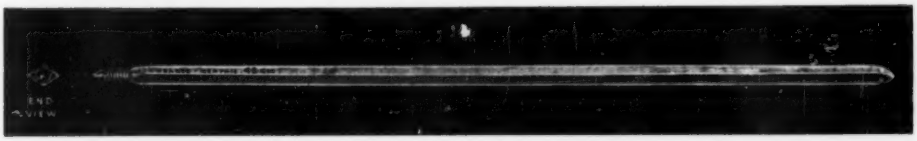

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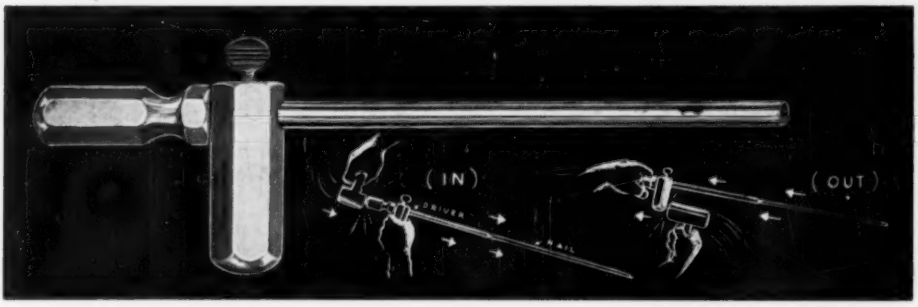

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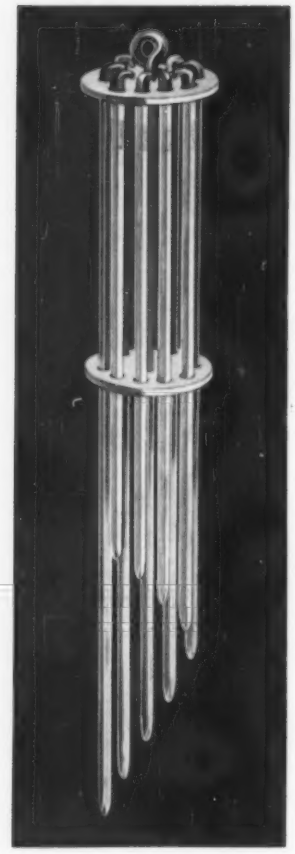

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You'll be glad to prescribe Alden-Pedic shoes

Alden-Pedic
SCIENTIFIC CONSTRUCTION

- Long inside counter
- Heavy gauge ribbed steel shank
- Right and left angled heels, long inside
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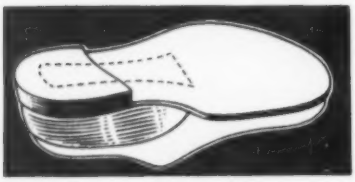

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Alden-Pedic lasts are designed to accommodate your prescribed corrections and insertions. Extreme sizes stocked. Many styles available. Top quality only.

Alden-Pedic lasts and shoes have been scientifically designed and tested to accommodate specific and general degrees of foot disabilities. Doctors who become familiar with the functional merit of this program will be glad to prescribe these shoes as a foundation in the treatment and correction of foot disabilities. We do not claim that these shoes will correct abnormal foot conditions, but they will provide the types of basic footwear necessary as a foundation in aiding foot trouble and in offering foot comfort. We know you will be glad to recommend them.

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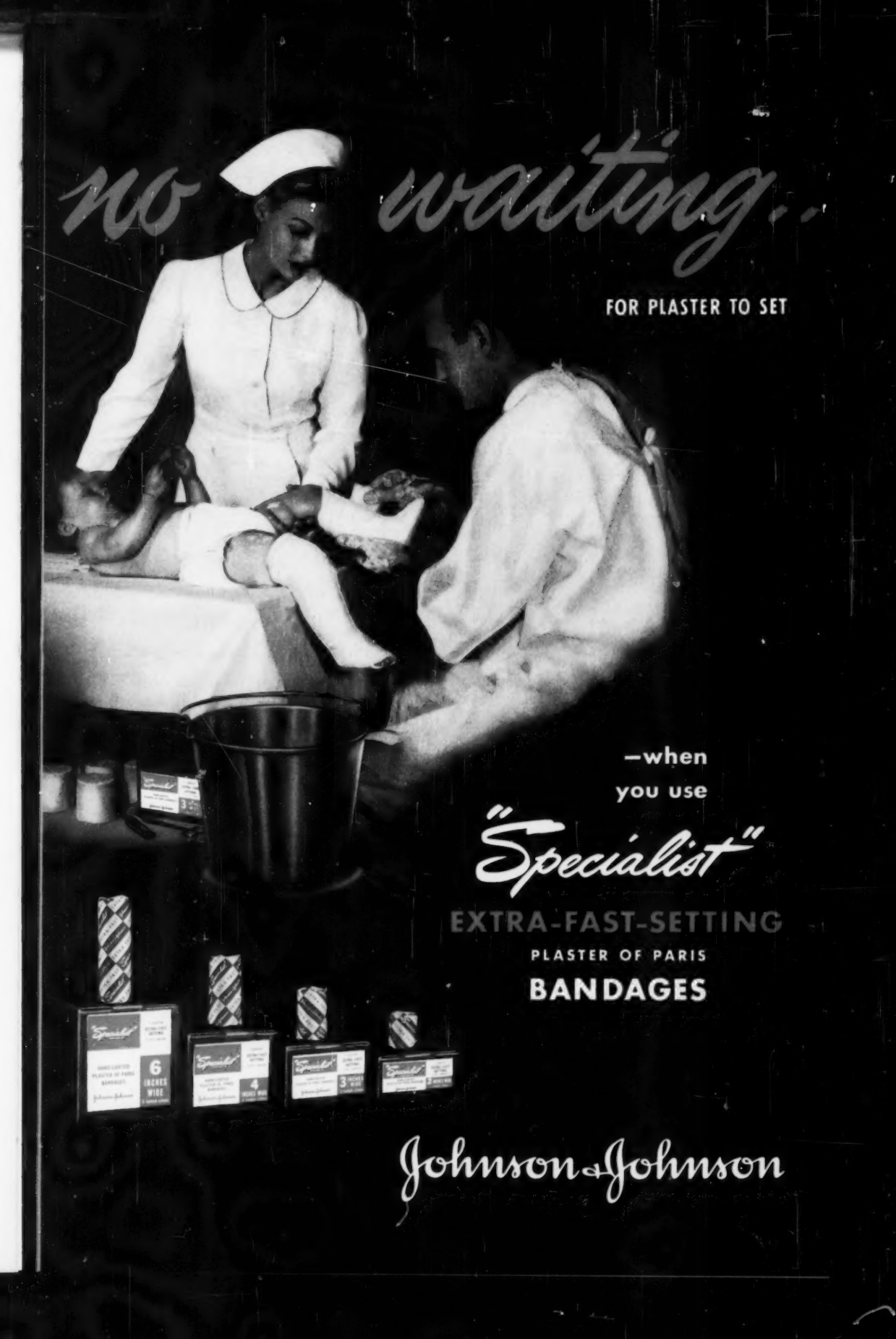
no waiting..
FOR PLASTER TO SET
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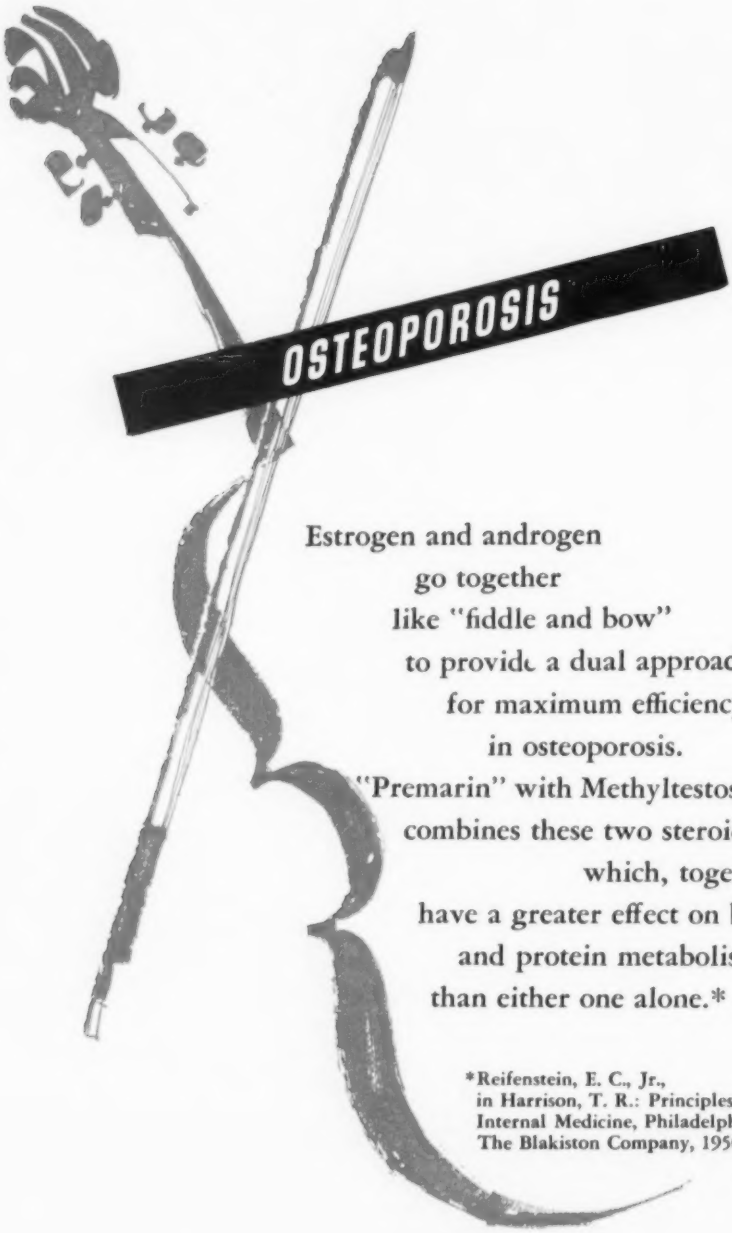
INCHES
WIDE
4
Johnson & Johnson



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go together
like "fiddle and bow"
to provide a dual approach
for maximum efficiency
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"Premarin" with Methyltestosterone
combines these two steroids
which, together,
have a greater effect on bone
and protein metabolism
than either one alone.*

*Reifenstein, E. C., Jr.,
in Harrison, T. R.: Principles of
Internal Medicine, Philadelphia,
The Blakiston Company, 1950, p. 655.

"PREMARIN"® with METHYLTESTOSTERONE

for combined estrogen-androgen therapy

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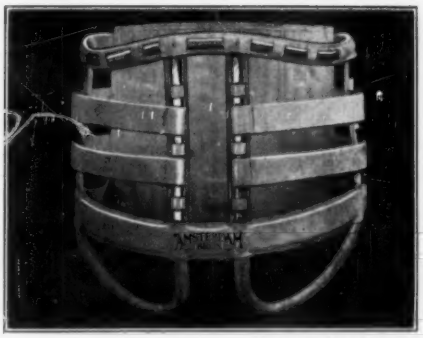
Heat or Humidity



Knight Spinal Brace
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Heat or humidity, wet or dry, there is no weather and no season when any brace or other orthopaedic appliance can be totally comfortable for any patient. Yet many common annoyances may be minimized (such as chafing from badly constructed or ill-fitted appliances) if the appliances are made correctly to fit properly. Almost 35 years of experience is practically a guarantee that AMSTERDAM appliances function in any season with the least discomfort. One case trial will prove this point.

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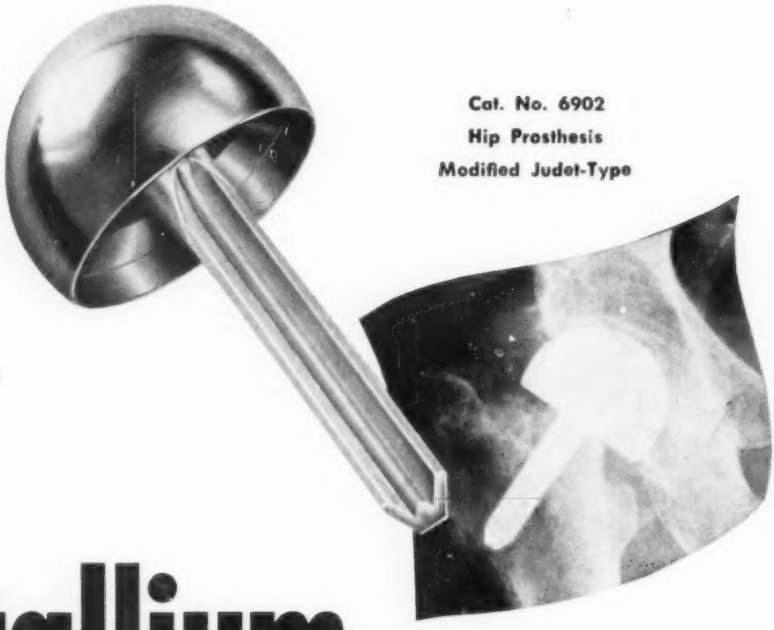

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Hip Prosthesis
Modified Judet-Type

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A strong, one-piece appliance that has proven very popular.
Vitallium prostheses excel as femoral head replacements because they are completely tolerated by human bone and tissue. First used in 1939, Vitallium hip prostheses have proven their strength, durability, and inertness through many years of clinical use.

The complete resistance of the passive Vitallium alloy to corrosion and wear makes it eminently suitable for endo-prostheses where appliances of other materials have proven less satisfactory.

The one-piece modified Judet-type Vitallium appliance consists of a head portion with an extended skirt and a stem of three-flanged hip nail design. The head is hollow for lightness and polished for best function. The three-flanged nail provides strength, ease of insertion and prevents rotation.

Available in two head diameters and seven nail lengths to meet individual requirements. Head diameters 1¾″ and 1⅞″. Nail lengths 2½″ to 5″ by ¼″ steps. Specify head diameter and nail length when ordering.

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Vitallium TROCHANTERIC NAIL-PLATES

NEUFELD TYPE

NOW AVAILABLE IN RESPONSE TO THE DEMAND OF THE MANY SURGEONS WHO ASKED FOR THEM

Like all Vitallium appliances, Vitallium Trochanteric Nail-Plates are completely inert in the human body. Their strength and engineered design permits contouring at the operative site for close adaptation to the bone. They have the characteristic "satin finish" of Vitallium appliances, reducing undesirable glare during the operation.

Effective fixation with Vitallium Neufeld-type nail-plates results in a feeling of security, better patient morale and shorter hospital confinement.

★ ★

Together with the Vitallium Jewett and McLaughlin-type inter-trochanteric appliances, the various Vitallium hip nails and screws, the Vitallium ready-made hip prostheses and the Bosworth-type splines, the addition of this Neufeld-type trochanteric nail-plate to the ever-increasing line of Vitallium surgical appliances provides the surgeon with a wider choice of fixation and repair appliances for the upper femoral region than is available from any other source.

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YOU CAN RELY UPON VITALLIUM SURGICAL APPLIANCES. They are made of a homogeneous, uniform alloy, completely passive, compatible and friendly to human bone and tissue.

INDICATED USES ABOUT THE HIP

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2. Trans-cervical fractures
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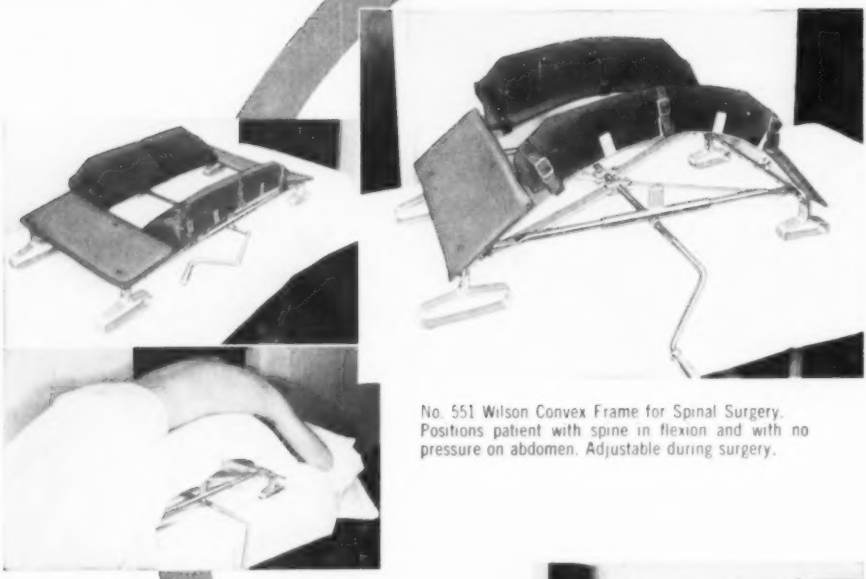
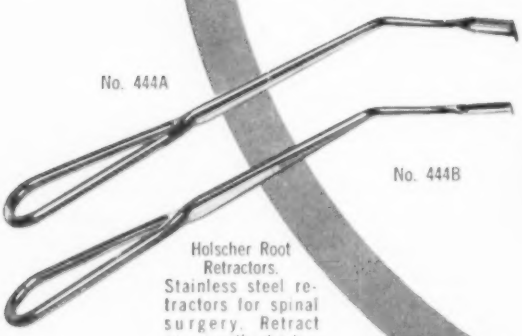
Zimmer TOOLS AND EQUIPMENT FOR SPINAL TREATMENT AND SURGERY



No. 551 Wilson Convex Frame for Spinal Surgery. Positions patient with spine in flexion and with no pressure on abdomen. Adjustable during surgery.



No. 444A

No. 444B

Holscher Root Retractors. Stainless steel retractors for spinal surgery. Retract nerves without interfering with use of rongeurs and other instruments.

No. 649 Pelvic Traction Belt. For treatment of slipped vertebral discs, sprains or minor fractures. Eliminates irritation due to adhesive traction and reduces swelling about knees and ankles.

ZIMMER MANUFACTURING CO. WARSAW, IND.

In Canada Available through selected surgical supply dealers or through our Agents, Fisher & Burpe, Ltd.

Zimmer

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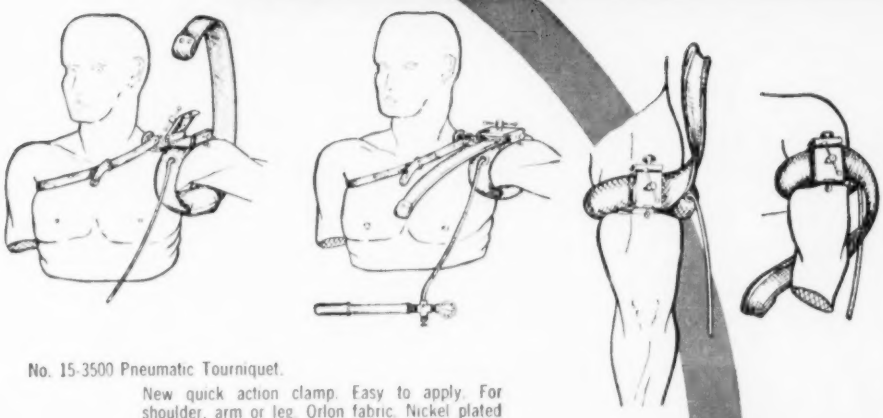
NEW *Zimmer* INSTRUMENTS AND EQUIPMENT



No. 15-3500 Pneumatic Tourniquet.
New quick action clamp. Easy to apply. For shoulder, arm or leg. Orlon fabric. Nickel plated metal parts. May be hooked to operating table.

No. 460 McReynolds Driver-Extractor with Adapters. Drives or extracts cloverleaf, Lottes or Hansen-Street pins, also Smith-Petersen or Jewett type nails. Eliminates use of hammer or mallet. Stainless steel.

No. 546 Orthopedic Hammer, Large.
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Aluminum construction, Non-sparking Nylon driving faces. Flattened, knurled handle.

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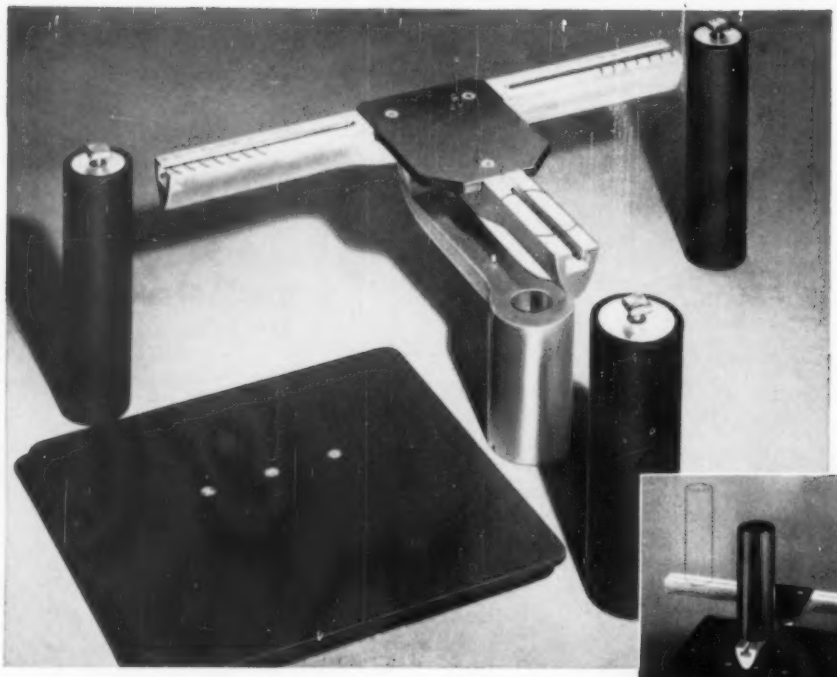
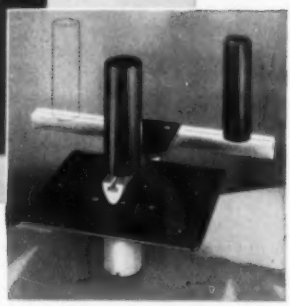
New! PELVIC ANCHOR SACRAL REST*

. . . for unilateral traction

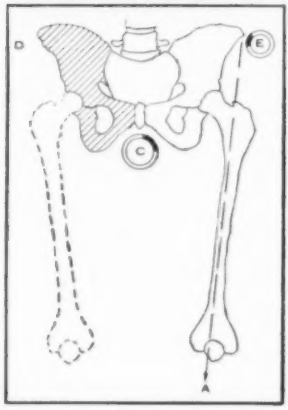




Castle introduces positive anchorage of the pelvis in orthopedic and traumatic surgical procedures. The Unit is adaptable to any major fracture table for use with child or adult patient to stabilize the pelvis in a centered position on the table.

AS ILLUSTRATED IN THE DIAGRAM, the Unilateral Traction Technique provides that when traction is applied to "A", counter-pressure is exerted at the ischium at "C" and on the ilium at "E". The combined counter-pressure at these two points of the innominate bone equals applied traction at "A". Tilting or pivoting of the pelvis is completely avoided—and of course, counter-traction on the opposite limb with all its attendant problems, is eliminated.

WRITE TODAY for complete information



70 YEARS OF PIONEERING DEVELOPMENT – Castle Sterilizers and Surgical Lights are recognized as the standard of engineering achievement and dependable performance throughout the world.

*Hall, Custis, et al. Jour. International College of Surg.; pp 30-33, January 1952.

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It's TENSOR Elastic Bandage because it's woven with live rubber threads

Tensor Elastic Bandage, as the photo clearly shows, has *twice* the elasticity of ordinary old-style all cotton bandages—and it snaps back all the way. Naturally—Tensor is woven with live rubber threads—not just cotton.

That's why Tensor enables you to apply *low* pressure as easily as higher pressures.

Pressure is *uniform*—with less danger of hyper-constriction—more comfort, more mobility for patients.

And you don't have to adjust Tensor as swelling goes up or down. Tensor adjusts itself.

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Under equal tension,
Tensor stretches approximately twice as far as old-style cotton bandages. And Tensor will snap back smoothly to its original length. That's why Tensor gives you greater control of pressure, requires no adjustment, is more comfortable to wear.

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ELASTIC BANDAGE
Woven with live rubber threads

BAUER & BLACK
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time
the fourth dimension in PREFERRED local anesthesia

Xylocaine® Hydrochloride (Astra) merits special consideration by the busy anesthesiologist and surgeon. Profound in depth and extensive in spread, its well-tolerated effect is more significantly measured by the time saved through its remarkably fast action, by which so much normally wasted "waiting time" is converted to productive "working time".

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Stocked by leading wholesale druggists and surgical supply houses as a ½%, 1% or 2% solution without Epinephrine and with Epinephrine 1:100,000. 2% solution is also supplied with Epinephrine 1:50,000. All solutions dispensed in 50cc. and 20cc. multiple dose vials, packed 5x50cc. or 5x20cc. to a carton.

XYLOCAINE® HCL

Pronounced Zī' lo'coin

(Brand of lidocaine hydrochloride*)

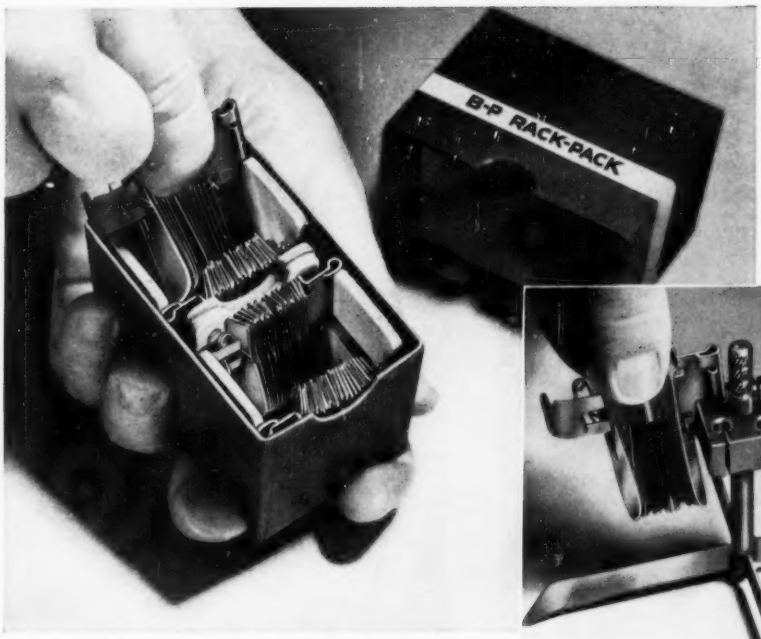
AN AQUEOUS SOLUTION

A 4th dimensional approach to preferred local anesthesia

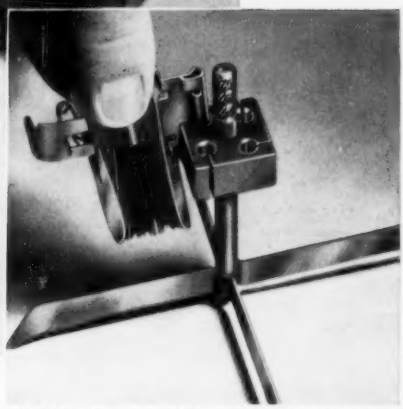
Bibliography available on request

ASTRA PHARMACEUTICAL PRODUCTS, INC. WORCESTER, MASS. U.S.A.

*U.S. Patent No. 2,441,498



Contains one gross of one size Blades on 4 Racks



RACKS with any size Blades fit the RACK-PACK Stand

A package is known by the COMPANY it keeps . . .

This **B-P RACK-PACK**

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is convincing proof! Just as you can depend upon RIB-BACK Blades to give you maximum cutting efficiency—you can rely on the RACK-PACK package to really save TIME and LABOR for your O.R. Personnel.

NO wrapping of individual packages
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The RACK-PACK fully protects the perfect cutting edges from damage in shipping, storing and pre-operative handling. V.P.I. rust inhibiting liner prevents corrosion. Blades already on RACK . . . ready for sterilization "*in a matter of seconds.*" AND —it costs the same as conventionally packaged Blades.

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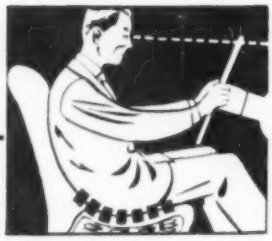
In Relieving Auto-Riding Backache

How Important Is Correct Posture?

WITHOUT SACRO-EASE



WITH SACRO-EASE

by THAD B. McCARTY, President

We have seen very few articles on this subject and we pose this question respectfully, in the hope that readers may call our attention to articles or information we have overlooked.

For more than 12 years we have been manufacturing Sacro-Ease, a posture-correction seat pad designed for use on the soft cushions of autos or over-stuffed chairs.

More than half of our sales are the result of doctors' recommendations. The results obtained seem to indicate that some physical means of posture correction may be of prime importance in relieving low-back pains while driving in an auto.

If your experience seems to bear out the importance of this, we would welcome the opportunity to let you test a Sacro-Ease pad—by using it yourself and/or handing it to patients who are in urgent need of relief.

Your local surgical appliance dealer may stock Sacro-Ease pads. If so, he will gladly furnish you with one to test. If he does not stock Sacro-Ease pads as yet, write us and we will ship you one with a memo bill for $9.75, postpaid. Test it for 30 days. At the end of that time, mail us your check or return the pad. We will refund return postage costs.

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THE Suction Socket Prosthesis has been one of the most important prosthetic developments in recent years. Based on entirely new conceptions of design, it is secured solely by muscular and suction action, and eliminates the hip joint and all belts and straps. With this prosthesis the wearer enjoys greater comfort, control, and utility than ever before possible.

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HANGER clients are examined and fitted by "Certified Suction Socket Fitters." These Fitters are certified after examination by a Certification Board composed of representatives of the industry and orthopaedic surgeons.

HANGER has been, and is today, a leader in the field of Suction Socket Prosthetics. We took an active part in the basic research with the Veterans' Administration, the Committee on Artificial Limbs of the National Research Council, and the Surgeons General of the Army and the Navy.

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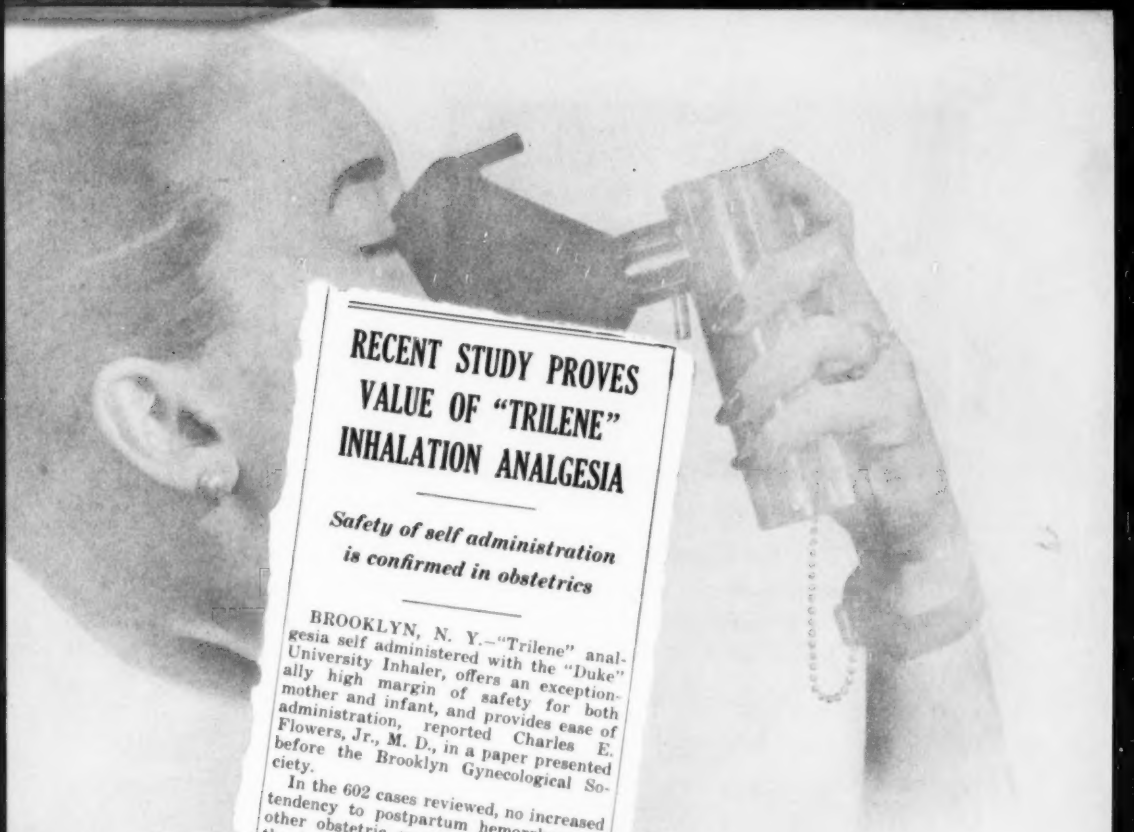

RECENT STUDY PROVES VALUE OF "TRILENE" INHALATION ANALGESIA

Safety of self administration is confirmed in obstetrics

BROOKLYN, N. Y.—"Trilene" analgesia self administered with the "Duke" University Inhaler, offers an exceptionally high margin of safety for both mother and infant, and provides ease of administration, reported Charles E. Flowers, Jr., M. D., in a paper presented before the Brooklyn Gynecological Society.

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Self administered with the "Duke" University Inhaler, "Trilene" analgesia is usually marked by smooth and rapid induction with minimum or no loss of consciousness. Inhalation is interrupted if unconsciousness occurs. Recovery is swift; nausea and vomiting are rarely noted.

"Trilene" is nonexplosive, and in the mixtures employed clinically is noninflammable in air and oxygen. "Trilene" may also be used as an analgesic adjunct while light planes of anesthesia are maintained with various anesthetic agents.

"Trilene,"® brand of highly purified trichlorethylene (Blue), is supplied in containers of 300 cc.

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"Duke" University Inhaler (Model-M)

Recommended for use with "Trilene" in obstetrics and surgery, the "Duke" University Inhaler is specially designed for economy, facility of handling and ready control of vapor concentration. It can be operated with ease and efficiency by adult or child in the doctor's office, in the hospital, in industrial dispensaries, in the home, or even enroute to the hospital.

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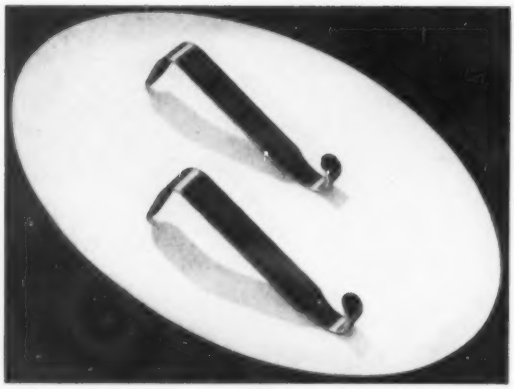

New & Simple

Taylor Spinal Retractor

This instrument has proven very effective when large muscle masses must be retracted in the lumbar region for arthrodesis and laminectomy. Leverage rather than direct pull is used to effect the retraction. *Set of two $11.00*

MEDICAL RESEARCH SPECIALTIES, Loma Linda, California

NEUFELD FEMORAL NAIL PLATE
Used for internal fixation of intertrochanteric and subtrochanteric fractures.
Write for descriptive literature.
MEDICAL RESEARCH SPECIALTIES
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new: *Sklar Multiple Action*

Bone Pin Cutter

CAT. No. 250-145

This new, streamlined Bone Pin Cutter adequately serves the needs of modern bone fixation—cuts all standard pins, nails or wire with unusual ease, safety and efficiency.

Shaped for easy insertion and manipulation in open wounds—chrome-plated to resist corrosion—this Sklar instrument is 15″ in length, and of long-handled construction for extra-strong leverage.

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Michele Trephines
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Sheldon Hemilaminectomy Retractor

Literature upon request.

CAUTION—if the name Sklar is not stamped on the instrument it is not a genuine Sklar product.

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38-04 Woodside Avenue, Long Island City 4, N. Y.

SABEL'S

PIGEON-TOE SHOE

Carried both White Elk and Tan Elk

RIGHT LEFT

Dotted line shows outline of normal shoe.

The Pigeon Toe Shoe carrying a definite outflare, is used on cases where there is an extreme toeing-in (i.e., walking pigeon-toed) and is known and called by the medical profession as a metatarsus varus deformity.

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to control fulminating sepsis

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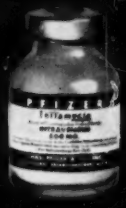
Vials of 250 mg. and 500 mg.



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*Bonica, J. J.: J.A.M.A., 150:1581, Dec. 20, 1952.

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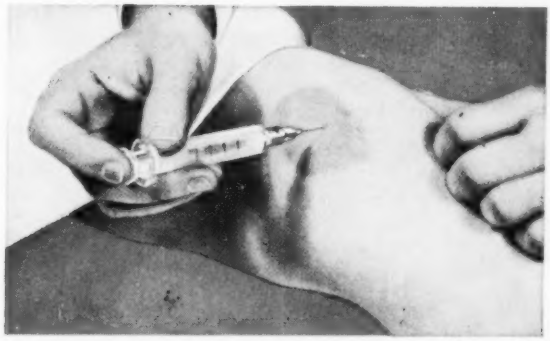
For the local treatment of individual joints in rheumatoid or osteoarthritis--



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ACETATE

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Brown, *et al.*,[1] administered 3,487 intra-articular injections of HYDROCORTONE Acetate to 480 patients with rheumatoid or osteoarthritis. In some of these patients, HYDROCORTONE was used in addition to other therapeutic measures and proved an excellent adjunct. Improvement was observed in 87 per cent. Local relief was obtained promptly, without systemic effects.

Literature on Request

1. Brown, E. M., Frain, J. B., Udell, L., and Hollander, J. L.: Paper presented at Annual Meeting, American Rheumatism Association, Chicago, Ill., June 6, 1952.

HYDROCORTONE *is the registered trade-mark of Merck & Co., Inc. for its brand of hydrocortisone. This substance was first made available to the world through Merck research and production.*

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for lighter, thinner, stronger casts

Davis & Geck's Melmac Orthopedic Composition is a melamine resin,† a new powder with catalyst which *doctors* add to the water in which they wet plaster bandages. With Melmac Orthopedic Composition, *doctors* need only *half the usual number of plaster of Paris bandages.* Melmac has been proven by extensive clinical trials.[1-3]

Greater comfort for patients

Cast A—ordinary plaster of Paris

Cast B, plaster *fortified* with Melmac, is half thickness of cast A and weighs less

6 great advantages of casts made with Melmac Orthopedic Composition

1. *Four times the early strength* and over twice the dry strength of ordinary plaster of Paris casts.
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5. Economical—*50% fewer bandages or less needed;* saves the doctor time.
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A unit of American Cyanamid Company

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Sutures and other surgical specialties

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Use of Melmac requires no new technique

To use bandages and splints wetted with Melmac solution, no new technique for applying casts need be learned. Plaster rolls or splints are soaked in the Melmac solution in the usual manner, the excess solution is pressed out, and the cast applied with the same technique as with ordinary plaster bandages and splints.

Note:
Cobey,[3] reports not one person allergic to Melmac in applying 1000 casts.

references:

1. A. W. Spittler, Col., (M.C.), U.S.A., J. J. Brennan, Lt. Col., (M.C.), U.S.A., J. W. Payne, Capt., U.S.A.F. (M.C.), American Academy of Orthopedic Surgeons, Jan. 26-31, 1952, Chicago, Illinois.
2. M. C. Cobey, M.D., F.A.C.S., Professor of Orthopedic Surgery, Georgetown University and Senior Attending Orthopedic Surgeon, Children's Hospital, Washington, D.C., The American Surgeon, Vol. XVIII, No. 4, April, 1952, pp. 413, 415.
3. M. C. Cobey, M.D., F.A.C.S., Washington, D.C., private communication.

Davis & Geck manufactures a complete line of surgical sutures. Diameter for diameter, the tensile strength of D&G Surgical Gut is unexcelled by any other brand.

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PLASTER CASTS THAT ARE HARD, LIGHTWEIGHT, ECONOMICAL AND EASILY APPLIED

KARMAC plaster of paris bandages and splints have been used exclusively for the past decade by surgeons who like the creamy smoothness and hard setting qualities of this special made product. And, it actually costs less.

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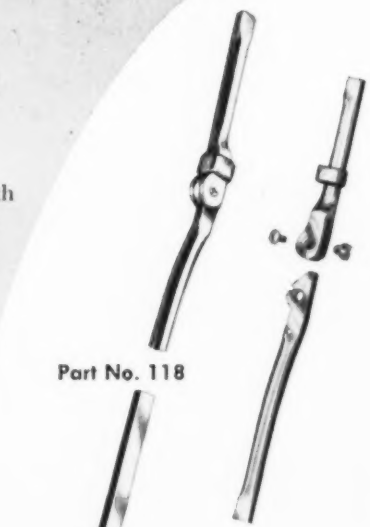
Aluminum braces compare with the strength of steel braces and plus added light-weight quality make them ideal for permanent wearers.

United States braces are manufactured from solid aluminum 24 S. T. bar stock. Buffed finish eliminates plating time and costs, thereby speeding up delivery and service to your patients.



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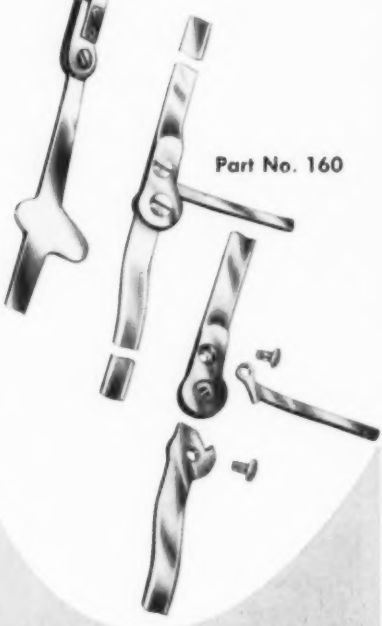

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UNITED STATES *Manufacturing* COMPANY

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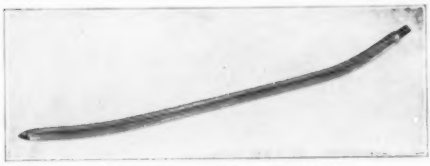
LOTTES TIBIAL NAIL



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Tibial Nail diameters: 5/16" and 3/8"

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The triflange nail is also available for femur, humerus, radius, and ulna.

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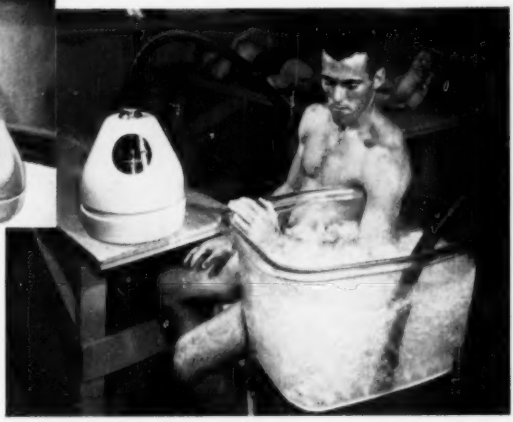
Vibra-Bath

...a most advanced hydrotherapy apparatus, which utilizes a new principle of hydromassage to introduce techniques not possible with conventional equipment.

The thermal and massage stimulus of this constantly agitated water is perhaps the most useful form of hydrotherapy in the after-care of amputation stumps, polio and in orthopedic cases.



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for firm lumbosacral support prescribe...

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These clinically tested supports extend high in back, curve in and under the gluteal region, which assists in anchoring the garment and relieves the tension of these muscles on their attachments.

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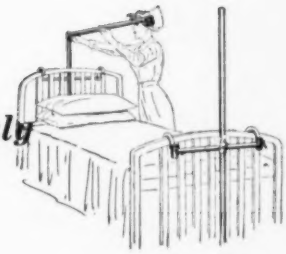

Stryker

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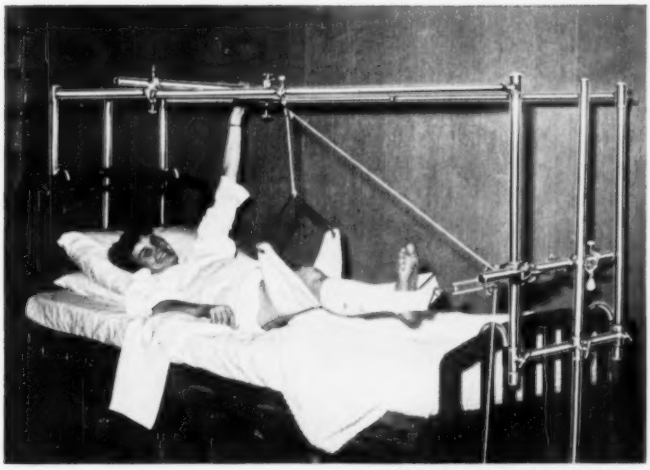

Double bar unit assembled and in use, showing patient in Russell's traction.

The Stryker Universal Overbed Frame can be attached to any ordinary bed or crib by a nurse or orderly *in minutes!* Available in single bar economy unit or double bar for heavy-duty use. Single bar unit may be purchased initially with component parts added later for double bar use. Various forms of traction are possible *plus* two outside overbed bars for use as patient exercisers. Plastic covered ends prevent marring. Chromium-plated. Quickly dismantled. Longest member telescopes from 52″ to 98″.

Orthopedic

ORTHOPEDIC FRAME COMPANY

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EASILY APPLIED MOIST HEAT

IN PRACTICALLY ALL OF YOUR THERAPY PROBLEMS THERE IS A PLACE FOR THE

HYDROCOLLATOR

Steam PACK

TRAUMATIC
ARTHRITIC
MYOFIBROSITIC
NEURO-MUSCULAR
REHABILITATION

The Hydrocollator Steam Pack is a fabric envelope containing a special heat retaining gel filler. When immersed and heated in water it becomes an efficient hot moist compress. It requires no wringing. There is no dripping. Simply wrap it in a turkish towel and apply to the area to be treated. Each application will give EFFECTIVE MOIST HEAT FOR AT LEAST 30 MINUTES. These packs can be used over and over.

When you prescribe supplementary thermotherapy in the home, the Steam Pack can be heated in hot water in any convenient vessel. For hospital or clinic the HYDROCOLLATOR Master Unit shown at lower right automatically maintains a supply of heated packs ready for immediate use.

EFFECTIVE:

- **Positive and prolonged hyperemia.**
- **Relief of spasm and pain.**
- **Preparation for rehabilitative exercise and therapy.**

CLINICALLY TESTED AND PROVED:

- **The steam pack is accepted by the Council on Physical Medicine and Rehabilitation (AMA).**
- **The master heating units are U L Approved.**
- **In use in leading hospitals and treatment centers.**

SPECIFICATIONS, PRICES AND USER LIST ON REQUEST

MANUFACTURED EXCLUSIVELY BY

CHATTANOOGA PHARMACAL CO.

CHATTANOOGA, TENNESSEE

HYDROCOLLATOR

This Master Heating Unit automatically maintains a constant supply of ready-to-use HYDROCOLLATOR Steam Packs. Temperature is thermostatically controlled. The heated pack is easily taken to the patient; thus you can treat several patients at the same time from the one unit. No need to transport patients to the heat source. No plumbing connections. Simply plug into your electrical outlet. Sturdy, handsome stainless steel construction.

the new absorbent cast padding WEBRIL

New* Curity WEBRIL *absorbs perspiration—helps maintain normal skin condition

More and more doctors are turning from conventional non-absorbent cast padding to new Webril bandages that absorb perspiration—that maintain healthy skin condition throughout immobilization.

Webril is easy to apply because it is conformable and sticks to itself, *needs no taping.*

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BANDAGES

BAUER & BLACK

Division of The Kendall Co.
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NEW Hirschstick Shoulder Splint for Immobilization

Overcomes need for frequent inspections and re-application needed when Velpeau bandage or sling and swathe is used. Extremely comfortable. Adjustable. In hundreds of cases of acromioclavicular separation this splint has never needed to be replaced because of inadequate immobilization.

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STANDARD OF QUALITY

especially developed for

Low-Back Syndrome

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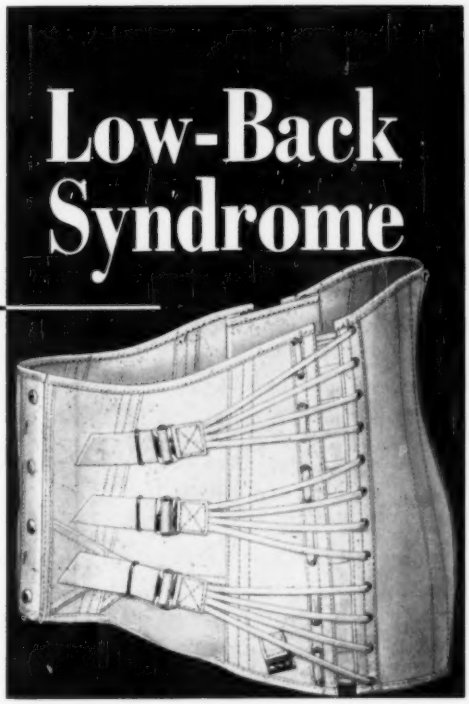

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Lumbo-sacral support incorporating traction and two-semi rigid steels. Three pull straps control traction; upper straps control lumbar region support, lower strap (attached to uplift panels in front) controls traction through trochanter area, increases lower abdominal support.

The complete line of TRUFORM Anatomical Supports includes a wide selection of lumbo-sacral garments. TRUFORM Lumbo-Sacral Supports are designed, under professional supervision, for a variety of conditions generally characterized by low back pain. Such TRUFORM supports are generally used for mild lordosis or spondylolisthesis and all provide effective fixation of the lower spine, varying in degree according to the depth of the garment.

These and other TRUFORM supports are available to your patients only through *surgical or prosthetic supply houses or orthopedic dealers*. Thus your patient is assured of professionally correct fitting by a trained technician.

For descriptions and illustrations of the complete TRUFORM line write for the TRUFORM Red Book, the profusely illustrated catalog which will serve as a valuable reference.

TRUFORM ***anatomical supports***

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Wanted

The Editorial Office of *The Journal* is constantly having calls for back issues of *The Journal* and desires to know where copies of the following issues may be obtained when needed:

THE AMERICAN JOURNAL OF ORTHOPEDIC SURGERY

1903–1904: Vol. I, Nos. 1, 2, 3, and 4; August, November 1903; February, May 1904.
1904–1905: Vol. II, Nos. 1, 2, 3, and 4; August, October 1904; January, April 1905.
1905–1906: Vol. III, Nos. 1, 2, 3, and 4; July, October 1905; January, April 1906.
1906–1907: Vol. IV, Nos. 1, 2, 3, and 4; July, October 1906; January, April 1907.
1907–1908: Vol. V, Nos. 1, 2, 3, and 4; July, October 1907; January, April 1908.
1908–1909: Vol. VI, Nos. 1, 2, 3, and 4; August, November 1908; February, May 1909.
1909–1910: Vol. VII, Nos. 1, 2, 3, and 4; August, November 1909; February, May 1910.
1910–1911: Vol. VIII, Nos. 1, 2, 3, and 4; August, November 1910; February, May 1911.
1911–1912: Vol. IX, Nos. 1, 2, 3, and 4; August, November 1911; February, May 1912.
1912–1913: Vol. X, Nos. 1, 2, 3, and 4; August, November 1912; February, May 1913.
1913–1914: Vol. XI, Nos. 1, 2, 3, and 4; July, October 1913; January, April 1914.
1914–1915: Vol. XII, Nos. 1, 2, 3, and 4; July, October 1914; January, April 1915.
1915: Vol. XIII, Nos. 1 and 2; July, October.
1916: Vol. XIV, All twelve issues.
1917: Vol. XV, Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10; January, February, March, April, May, June, July, August, September, and October.
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THE JOURNAL OF ORTHOPAEDIC SURGERY

1919: Vol. I (Old Series Vol. XVII), Nos. 1, 2, 3, 4, 5, 6, 7, 9, 10, 11, and 12; January, February, March, April, May, June, July, September, October, November, and December.
1920: Vol. II (Old Series Vol. XVIII), all twelve issues.
1921: Vol. III (Old Series Vol. XIX), Nos. 1, 2, 3, 4, 6, 9, 10, 11, and 12; January, February, March, April, June, September, October, November, and December.

THE JOURNAL OF BONE AND JOINT SURGERY

1922: Vol. IV (Old Series Vol. XX), Nos. 1, 2, and 3; January, April, and July.
1923: Vol. V (Old Series Vol. XXI), Nos. 1, 2, 3, and 4; January, April, July, and October.
1924: Vol. VI (Old Series Vol. XXII), Nos. 1, 2, 3, and 4; January, April, July, and October.
1925: Vol. VII (Old Series Vol. XXIII), No. 1; January.
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1929: Vol. XI (Old Series Vol. XXVII), Nos. 1, 2, and 4; January, April, and October.
1930: Vol. XII (Old Series Vol. XXVIII), Nos. 1 and 2; January and April.
1931: Vol. XIII (Old Series Vol. XXIX), No. 1; January.
1932: Vol. XIV (Old Series Vol. XXX), No. 4; October.
1933: Vol. XV (Old Series Vol. XXXI), No. 1; January.
1934: Vol. XVI (Old Series Vol. XXXII), No. 4; October.
1935: Vol. XVII (Old Series Vol. XXXIII), Nos. 1, 2, 3, and 4; January, April, July, and October.
1937: Vol. XIX (Old Series Vol. XXXV), Nos. 1, 3, and 4; January, July, and October.
1938: Vol. XX (Old Series Vol. XXXVI), Nos. 1, 2, 3, and 4; January, April, July, and October.
1939: Vol. XXI (Old Series Vol. XXXVII), Nos. 1, 2, 3, and 4; January, April, July, and October.
1940: Vol. XXII (Old Series Vol. XXXVIII), No. 1; January.
1941: Vol. XXIII (Old Series Vol. XXXIX), No. 1; January.
1944: Vol. XXVI (Old Series Vol. XLII), Nos. 1, 2, 3, and 4; January, April, July, and October.
1945: Vol. XXVII (Old Series Vol. XLIII), No. 2; April.
1947: Vol. XXIX (Old Series Vol. XLV), Nos. 1, 2, and 3; January, April, and July.
1948: Vol. XXX-A, No. 1; January.

Any reader having copies of the above, which he is willing to dispose of, is requested to correspond with the Editor.

In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*

The Journal of Bone and Joint Surgery

American Volume

Fifty Years

With this issue *The Journal* completes fifty years of publication. In August 1903, the first issue appeared under the name of *The American Journal of Orthopaedic Surgery*. It was published then as now by The American Orthopaedic Association, replacing the Transactions of that Association, the first two volumes of which were published in 1889, and which had appeared annually thereafter through 1902. Whereas the Transactions contained papers by members only and were distributed largely to the membership, the pages of the new publication were, from the beginning, open to all surgeons throughout the United States and Canada to record their experiences and present their achievements in this new and growing branch of surgery. Abstracts of current world orthopaedic literature had been included in Volume XV (1902) of Transactions; these were continued in the new publication. One can hardly doubt that the founders wished their *Journal* to become representative of American Orthopaedic Surgery. That they recognized the value of free interchange of ideas among diverse schools of thought is evident in the section devoted to abstracts.

Gradually, *The Journal* came to include contributions from many American and Canadian surgeons not members of the Association; occasionally articles appeared that were written by surgeons from other countries, interested in orthopaedics. As contributions to *The Journal* became more representative of orthopaedic developments throughout the world, so too did the readership of *The Journal* become more widely distributed.

With the formation of The British Orthopaedic Association at the close of World War I, *The Journal* became its official publication. Cooperation between the orthopaedic surgeons of this country and surgeons on the other side of the Atlantic had led to a joint presentation of achievement; to signalize the broader aim, the title was changed to *The Journal of Orthopaedic Surgery*. In 1922, the title became *The Journal of Bone and Joint Surgery*, a name felt at that time to better express the scope of the field of surgery which *The Journal* represented. In 1935 *The Journal* became the official organ of The American Academy of Orthopaedic Surgeons; in 1950, of The American Society for Surgery of the Hand.

In 1948 came the division of *The Journal of Bone and Joint Surgery* into two volumes, Volume A representative of American Orthopaedic Surgery and Volume B of British Orthopaedic Surgery, each complementing the other and each published by the orthopaedic surgeons of the respective country. The ensuing five years of copublication have witnessed a marked increase in the amount of material published in the combined volumes. Such added features as Proceedings have enabled *Journal* readers to keep in closer touch with orthopaedic development not only in their own countries but also in other countries.

That *The Journal* has grown is evident from comparison of the total number of pages of the 1947 Volume which, including the index, was 1,152 with the total pages of the 1952 Volumes A and B which, taken together, numbered 1,804.

At the completion of fifty years *The Journal* recognizes the ever-increasing responsibility of adequately recording the developments of a large and growing division of surgery. The many phases of present-day orthopaedics, new developments in the basic sciences, especially in physiology and anatomy, as they are related to orthopaedic surgery—all these must find space in *The Journal* of tomorrow; pages must be available for a growing volume of articles devoted to fundamental clinical studies and improved techniques.

To keep its readers in touch with these developments is the task to which *The Journal* is dedicated. To meet this challenge the Editorial Board will do its best.

A HISTORICAL REVIEW OF THE STUDIES AND INVESTIGATIONS MADE IN RELATION TO HUMAN GAIT

To judge from the literature there is every indication that the interest which the profession shows in the mechanics of human gait is on the increase. This is directly attributable to the considerable advances which have been made in the study of locomotion; these can no longer be denied recognition or be treated with indifference. Nevertheless, the road which led to the present only relatively adequate knowledge of the subject was very long and hard.

The tracing of the roots of our knowledge of human gait into the past would lead us almost into antiquity. From time to time, anatomists, mathematicians, and physicists have occupied themselves with problems concerning gait. The distinction of being the pathfinder should go to Borelli (1608–1679), not so much for what he did in the mechanical analysis of locomotion itself but because of his fundamental concept of muscle action,—a concept which, as Sherrington himself pointed out, anticipated the ideas of the nineteenth century and may well be considered the forerunner of Sherrington's own law of reciprocal innervation. Borelli's concept is so essential for the study of locomotion and for the analysis of gait in general that it must be considered one of the foundations of the development of our knowledge in this particular field. Borelli was also the first to determine the center of gravity, which is of fundamental importance in the calculation of the events of locomotion. His book *De Motu Animalium* was published in 1682, three years after his death. Possibly Borelli was inspired by Descartes, whose work on the "passions of the soul" had appeared in 1649; Descartes approached the problem of antagonistic reciprocity from a philosophical rather than from a naturalistic point of view. Borelli describes the forward displacement of the center of gravity beyond the supporting area and the manner in which the forward swinging of the limbs saves the body from losing balance (*et tunc ruina illa subito reparatur*). This is in fact the foundation of the concept of propulsion and restraint in gait.

Following this, very little was accomplished in the study of locomotion for more than one hundred years. Albrecht von Haller (1708–1777), although he must have known of Borelli's work, fails, in the fourth volume of his *Elementa Physiologicae Corporis Humani* (1762), to recognize the reciprocal relationship of the synergist and the antagonist, when he speaks of the electrical irritability of the muscles (peculiarly enough, without mentioning the work of his contemporary, Galvani).

It was reserved for the men in the first half of the nineteenth century to continue Borelli's work. They began the modern scientific elaboration of the study of the mechanism of gait. The era is marked by the work of the brothers Wilhelm and Edward Weber (*Die Mechanik der Gehwerkzeuge*, 1836). The period might well be called the observational period of the studies on gait. The Weber brothers observed and measured the alternation of swing and support, the inclinations of the trunk in either phase, the relationship between the duration and the length of the step, and the rhythm of alternation in walking and running, setting up a special pattern for each. They also initiated investigations into the muscle effort involved in propulsion and restraint. When one considers the rather primitive means at the disposal of the Weber brothers, the accuracy of their observations is rather astounding. For instance, they determined the swinging time of the cadaver leg at 0.355 second; this comes very close to the passive-swinging time of the leg of a living person at 0.346 second and the swinging time of the leg in gait at 0.332 second. Their only error was to assume that in the forward swing the musculature played no role,—a point which was contested and disproved by Duchenne, Carlet, and others.

The period which followed, that of visual recording, was the period in which photog-

raphy and kymography were introduced. Yet about four decades elapsed before the work of Marey (*La machine animale*, Paris, 1873) appeared. Carlet, working in Marey's laboratories, used the kymograph to record the length and duration of the step, swinging and standing time, and the inclination of the body ("Essai expérimentale sur la locomotion humaine", Annales de Science Naturelle, Section Zoologique. Vol. XV, 1872). Marey was the first to use photography in analyzing the body movements during locomotion and to register the movements of selected points of the body. The subject was clad in black with white stripes which indicated the pathways of these points. Photographic studies were made which resulted in the development of path curves very similar to those established two decades later by Braune and Fischer.

The names of Muybridge (1882), Anschütz and Londe (1891) should be mentioned. These men made steady progress in the art of photographic recording which, at the time of Marey, had already attained a certain degree of perfection.

Once photography was established as a medium of recording the phases of gait, the way was open for calculative investigations on velocities, acceleration, and moving forces; such calculations characterized the next period of research of which the outstanding monument is the classic work of Braune and Fischer, *Der Gang des Menschen* (1895),—a work which represents the highest achievement yet attained in the calculative analysis of the essential factors of human gait. For their experiments Braune and Fischer used a method similar to that used by Marey. They substituted Geisler tubes for the white stripes; and, according to their own statement, it took from six to eight hours to get their subject ready for the trial. They first ascertained by photographic methods the pathways of locomotion for different points of the body, with or without load, marked by the tubes. The points were the head, the shoulders, the wrists, the hips, the knees, and the ankles,—eleven points in all. During the first part of their work, the investigation was devoted to the graphic presentation of the pathways of human gait. By relating their photographs to a three-coordinate system, they could tabulate by trigonometric computations the actual numerical values of the pathways of human gait. For this purpose they divided the double step into thirty-one distinct phases. Subsequently, the pathways of the common center of gravity were studied by Fischer alone and the values obtained were tabulated in a similar manner. Then, from these pathways the velocities could be calculated, while from the velocities, the acceleration could be calculated trigonometrically. The final objective of the study was to ascertain the moving force lying behind acceleration, velocity, and the pathways. This also was arrived at by trigonometric calculations from the accelerations established, so that in the end tables could be presented which contained all the fluctuations of floor pressure for each of the thirty-one phases into which the double step was divided. This is the subject of the sixth and final part of this classic on human gait,—namely, the ascertaining of the effective force behind locomotor performance with its several components (swing, propulsion, and restraint), all represented by the fluctuation of the floor reaction.

The decades which immediately followed the work of Braune and Fischer saw comparatively little advance in the study of human locomotion, until a new approach to human gait opened up wider possibilities. This new and most recent approach to the analysis of gait is the investigation of the role played by each individual muscle. By assembling the separate muscle activities one arrives at a pattern which is not unlike a symphonic score, each muscle entering into the pattern at a certain moment and leaving it at another. One of the earliest and foremost contributors to this phase of investigation is Richard Scherb of Zurich. Basing his work upon the studies of the movements of the different portions of the body during gait, as they had been established by Braune and Fischer, Scherb first defined the pattern of sequence of the muscle action of the lower extremities. It must be pointed out that his earlier studies were carried out by purely palpatory methods on the treadmill. It was only later, with the introduction of the electromyograph, that his method

could be refined. Even in his latest work on the "kinetic diagnostic analysis of the disturbances of the gait" (1952), he presents the results from his palpatory methods together with the results from his electromyographic studies. His work covers not only normal gait patterns but also such pathological gait conditions as those found in static deformities, poliomyelitis, spastic paralysis, and hemiplegia.

An indirect contribution to the study of gait, but one intimately related to it, is the work of Hans von Baeyer. In 1933, he reported to the International Orthopaedic Congress what he called the synopsis of muscle function. Particularly, his work was concerned with the muscle combinations acting upon the extremities. This research is fundamental in the study of gait because, in essence, it is a study and an analysis of muscle actions as they effect not the periphery but the proximal end of the lever arm,—quite in contrast to the usual concept of a freely movable peripheral end. His was the concept of the closed kinetic chain,—that is, a situation in which peripheral resistance much exceeds central resistance. This is amply documented by the mechanism of the gait and is, in fact, the background of the mechanical concepts of propulsion and restraint.

It was only with the realization that the kinetics of human gait reveals and enlightens many situations which directly concern the practising physician that the need for more complete knowledge of the dynamic aspects of gait became apparent. Many surgeons who had looked askance at the kinesiology of gait as being theoretical balderdash were now awakening to the fact that it is actually a source of valuable and even indispensable guidance in their own clinical practice. We are glad to see that the last few decades have become much more fruitful and that contributions on the study of the mechanics of gait are now being accepted liberally by scientific journals.

Earlier physicians concerned themselves with the pressures of the floor reactions and their variations under pathological conditions. In this, the book by Dudley Morton on the foot has been a guiding factor.

It is here that we must give credit to the work of R. Plato Schwartz. He started his investigations of gait by a basograph recording of pressure at contact points of the foot. His publications have appeared in *The Journal of Bone and Joint Surgery* in 1928, 1932, 1933, 1934, 1935, 1936, 1937, and 1947, in his own name or in cooperation with A. L. Heath. Schwartz made use of the pneumatic sole of Carlet in order to determine the change of pressure at the contact points of the foot. He continued with ever-improving methods, availing himself finally of electrical contact apparatus (somewhat analogous to that used by Scherb in 1936) to register the actions of the different muscles in gait and to determine the time of pressure of the heel, the big toe, and the little toe, and to present it graphically. In his most recent publication (1947) he deals with quantitative investigation of the changing pressure and takes advantage of the pressure sensitivity of carbon discs to record pressure changes as they exist in normal as well as in pathological conditions of the foot.

In more recent years the interest in the analysis of gait has turned more to the dynamic side of the problem. This aspect, which had been so ably and persistently inaugurated by Scherb and others, has found its foremost votary and promoter in Verne T. Inman of San Francisco. His studies on the action of individual muscles cover many situations. So far as gait is concerned, his outstanding contribution is the electromyographic analysis of the hip muscles in their static as well as their dynamic functions and both in qualitative and quantitative respects. He has been able to present electromyographic tables upon the dynamic dysfunction of muscles which are engaged in the performance of locomotion. To one who is conversant with the work of Scherb as well as that of Inman, it will be most gratifying to find how closely the results of the former's palpatory method tally with the results of the latter's more refined technique. This conformity can only add to the credit of both of these leaders. Inman especially has enriched our knowledge of the mechanics of gait by establishing the intensity as well as the duration of the muscle effort and thereby

(*Continued on page 728*)

THE MAJOR DETERMINANTS IN NORMAL AND PATHOLOGICAL GAIT *†

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INTRODUCTION

Human locomotion is a phenomenon of the most extraordinary complexity. Although the primary objective of locomotion may be simply stated as the translation of the body from one point to another by means of a bipedal gait, its analysis requires the collection of an enormous amount of data in order to follow the entire cycle of events. It is evident that a complete description of locomotion involves consideration of both the kinematics and kinetics of the extremities in all their manifold details; but such knowledge, even if complete, would be of little value to the orthopaedic surgeon unless it were integrated to evolve a concept of locomotion from which deductions can be drawn and applied to the analysis of the clinical problems which daily confront him. However, the synthesis of all the elements which simultaneously participate in locomotion, although an ideal worthy of achievement, is a task of such magnitude and difficulty that its early attainment cannot be expected. Therefore, it is our purpose to limit ourselves in this paper to a consideration of what we have called the primary determinants of human locomotion and to examine these determinants in relationship to pathological gait. It is our expectation that, by an appreciation of these fundamental determinants, the orthopaedic surgeon will be able to analyze disorders of locomotion with greater precision and to apply corrective measures with a fuller understanding of the interrelationships which exist between the various segments of the locomotor mechanism.

METHODS

The data upon which the present analysis of the fundamental determinants of gait is based were obtained with the aid of a variety of techniques. Since a study of locomotion involves the recording and the measurement of the magnitudes, directions, and rates of change of the translations, rotations, and forces occurring in the body with respect to the three coordinate axes in space, a number of methods must be employed in order to obtain the different types of data. No one technique will yield all the desired information. The choice of a particular method is dictated by such factors as the simplicity of recording, the ease of reduction of the data, and the accuracy of the findings. The details of the techniques employed have been described elsewhere [2] and, for reasons of space, cannot be discussed here; but they will be briefly mentioned. The displacements of the extremities were determined by several methods. One of these consisted of a glass walkway which permitted the study of the displacements in the three planes of space simultaneously. By measurement of the displacements as a function of time, the velocities and accelerations of selected points were calculated. Displacements in the sagittal plane were also obtained by an interrupted-light technique similar to that employed by Marey. This method permitted the calculation of the components of velocity and acceleration in the plane of progression with great accuracy. Electrical accelerometers were used to check the findings but were found to be inferior to methods of graphonumerical differentiation. The transverse rotations of the limb segments were most accurately determined by the insertion of

* Based on two papers read at the Joint Meeting of the Orthopaedic Associations, London, July 1, 1952.

† A contribution from the Biomechanics Group aided by grants from The National Foundation for Infantile Paralysis, Inc., and the National Research Council, Advisory Committee on Artificial Limbs.

pins into the bones. High-speed motion-picture photography proved to be of qualitative value only, but it was useful for the examination of motions of minor magnitude. In some instances cineradiography had a limited usefulness. The gravitational and muscle forces were studied by means of electromyography and by the use of force plates. Electromyography was most valuable in determining the precise phase of muscle activity. The force plate, which will be mentioned in greater detail later, allowed the direct measuring from the ground reactions the magnitudes of vertical force, torque, and horizontal shears, as well as the center of pressure on the foot. In addition special techniques were devised to determine physical constants, such as the centers of gravity, the relative masses of the segments, and the calculation of the mass moments of inertia. The data presented are for level walking at the cadence normal to the subject investigated.

THE CENTER OF GRAVITY OF THE BODY

In order to present a simplified concept of the phenomena of locomotion, it is convenient to consider the behavior of the center of gravity of the body during the cycle of motion. By so doing we introduce an abstract conception, since we assume that the entire weight of the body is concentrated at that point. The limbs may be regarded, therefore, as weightless levers of the body. This enables us to avoid for the most part the discussion of the forces acting upon the individual segments and to limit consideration to those operating at or influencing the center of gravity itself. In this way, we are able to treat of locomotion in a somewhat idealized fashion which permits the analysis and synthesis of the fundamental features concerned in the translation of the body and its energy requirements. Furthermore, the selection of the center of gravity as a point of reference from which to depart possesses distinct advantages since *the displacement pattern of the center of gravity may be regarded as constituting the summation or end result of all forces and motions acting upon and concerned with the translation of the body from one point to another during locomotion.*

Under static conditions, the center of gravity of the body has been determined by a number of methods. Its position was found in cadavera by the familiar experimental technique of double suspension and in living subjects by the use of a balanced beam and by calculation from volume contour maps of the body. The results from these several methods are all in reasonable agreement. In adult males and females, it is estimated that the center of gravity of the body lies in the mid-line at a distance from the ground corresponding to about 55 per cent. of the total stature (individual variations being ± 1.25 per cent.) [1]. With reference to the vertebral column, the center of gravity occupies a position just anterior to the second sacral vertebra.

The Displacement of the Center of Gravity

The rhythmic upward and downward displacement of the body is a feature of locomotion which is familiar to all. It may be seen subjectively in the upward and downward fluctuation of distant objects on which the vision is fixed, and objectively in the "bobbing" up and down of the head of a person, very noticeable when he is walking out of step in the company of others. These fluctuations reflect the displacement of the center of gravity in the vertical plane. The pathway described by the center of gravity in the plane of progression is a smooth undulating or sinusoidal curve. The form of this curve may often be seen when a small boy holding a piece of chalk against his body at approximately the level of his center of gravity scribbles a wavy line on a wall or fence as he walks parallel to it (Fig. 1). The laboratory methods of recording the displacement of the center of gravity are no more than an elaboration of this childhood pastime. The position of the center of gravity is marked upon the body and the subject walks along a wall on which a coordinate system has been drawn. He is photographed by synchronized cameras from different aspects and, after correction for parallax, the displacements are determined in the various axes and

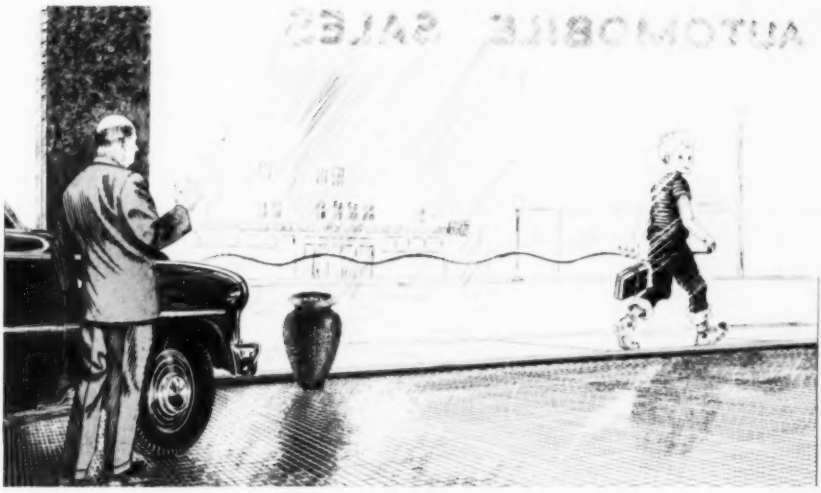


FIG. 1

The line drawn on the glass window represents the approximate pathway of the center of gravity of the body.

are related to the precise phase of the locomotor cycle and to the ordinate of time.

In normal level walking, the center of gravity of the body describes a smooth regular sinusoidal curve in the plane of progression. From this curve, it is determined that the center of gravity is displaced twice in a vertical direction during the cycle of motion from the position of the heel-strike of one foot to the subsequent heel-strike of the same foot, that is, as the body passes successively in a double pace over first the right limb and then the left. The total amount of this vertical displacement in normal adult males is about one and eight-tenths inches; individual variations are so small that they may be neglected. The summits of these oscillations occur at 25 and 75 per cent. of the cycle, each corresponding to the middle of the stance phase of the supporting limb; the opposite limb is at this time in the middle of the swing phase. At 50 per cent., or the middle of the cycle, the center of gravity falls to its lowest level; this position corresponds to the interval of double weight-bearing when both feet are in contact with the ground. As the curve is followed in its ascent and descent, it is found to fluctuate evenly between the maxima and minima of the displacement, with few if any irregularities. At its maximum vertical displacement, the center of gravity of the body always lies slightly below the level of the same center when the subject is standing. In other words, a person is slightly shorter when he is walking than when he is standing, so that, if he were to walk through a tunnel the height of which corresponds exactly to his standing height, he could do so without fear of bumping his head, as he would have nearly one-half inch of clearance.

The center of gravity of the body is also displaced laterally in the horizontal plane. Relative to the plane of progression, the center of gravity describes a sinusoidal curve, the summits of which alternately pass to the right and to the left in association with the support of the weight-bearing extremity. The curve is smoothly undulating without irregularities and it is similar in form to that of the vertical displacement. The magnitude of the horizontal displacement in normal level walking is approximately one and three-quarter inches as measured from the extremes of the deviation from right to left.

When the vertical and horizontal displacements of the center of gravity of the body are combined and are projected on the coronal plane, they are found to describe an almost perfect figure of eight, occupying approximately a two-inch square, since the vertical and horizontal deviations are almost equal.

A three-dimensional picture of the pathway of the center of gravity in the line of progression is that of a spiral along which the center moves with almost even velocity (Fig. 2). In a single cycle of locomotion from the right heel-strike to the left toe-off, the center of gravity may be followed as it rises smoothly to a summit at 25 per cent. of the cycle; but at the same time it deviates to the right. As the center begins to descend, it smoothly deviates toward the left to continue this deviation as it once more begins to rise to a second summit at 75 per cent. of the cycle. When the second summit is reached and the center proceeds to fall, it begins to return gradually to the right and has reached the central axis of the forward motion as the cycle is completed.

THE DETERMINANTS OF GAIT

Newton's first law of motion states that every body continues in its state of rest or of uniform motion in a straight line, unless it be compelled by impressed force to change that state. Translation of a body in a straight line with the least expenditure of energy may be achieved mechanically by means of the wheel, but it is quite impossible by means of bipedal gait. The next most economical method would be translation of the body, as in locomotion, through a sinusoidal pathway of low amplitude in which the deflections are gradual. Since force is equal to mass times acceleration ($F = ma$) and acceleration is a function of time ($a = v, t$), abrupt changes in the direction of motion compel a high expenditure of energy. In translating the center of gravity through a smooth undulating pathway of low amplitude, the human body conserves energy; and, as we shall see in considering pathological gait, the body will make every attempt to continue to conserve energy. Developmentally, the achievement of this pattern of progression would appear to have come about by natural experiment. In children the pattern of locomotion is variable and irregular, and it does not become stable until approximately the seventh year of life. Therefore, it is of importance to analyze the factors which determine the pathway of the center of gravity, since from them we may gain considerable understanding of the locomotor mechanism and appreciate the influence of pathological abnormality, especially as regards the energy cost to the body. In order to do so, it is necessary to introduce at first certain purely theoretical considerations.

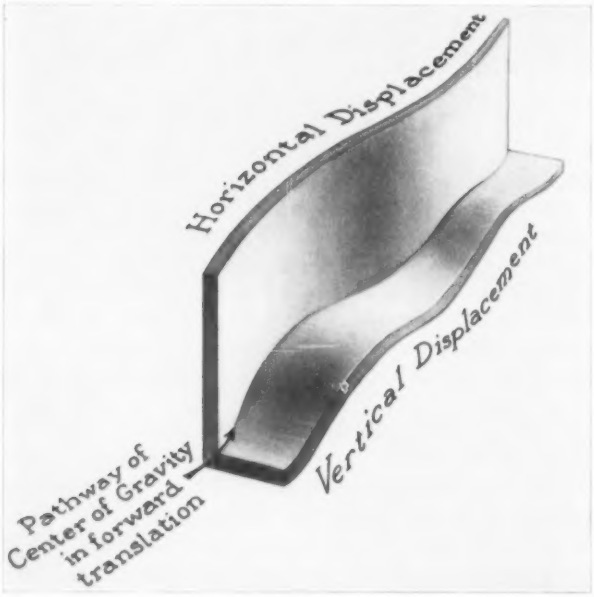


FIG. 2

The intersection of the horizontal and the vertical displacements produces the pathway of the center of gravity in locomotion.

Compass Gait

For analytical purposes, let us consider the behavior of the center of gravity in a bipedal system in which the lower extremities are represented by rigid levers without foot.

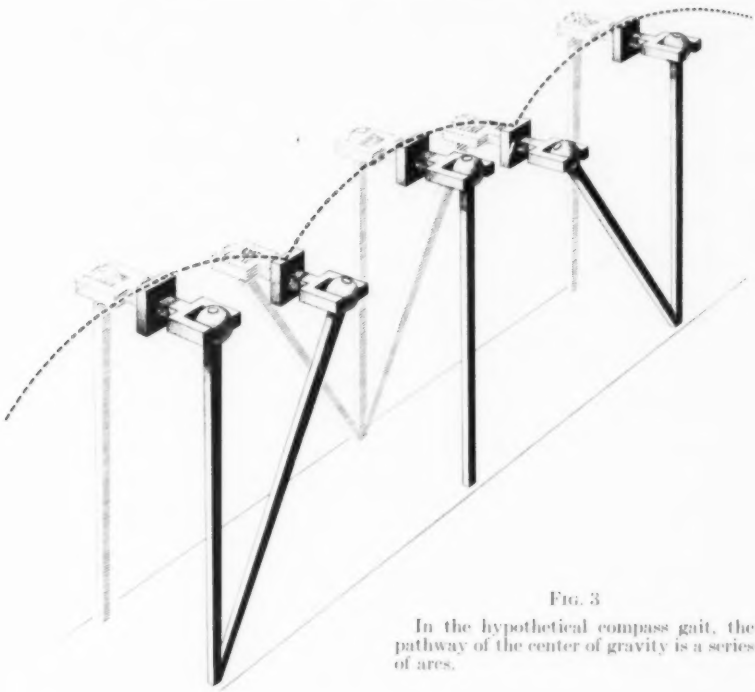


FIG. 3

In the hypothetical compass gait, the pathway of the center of gravity is a series of arcs.

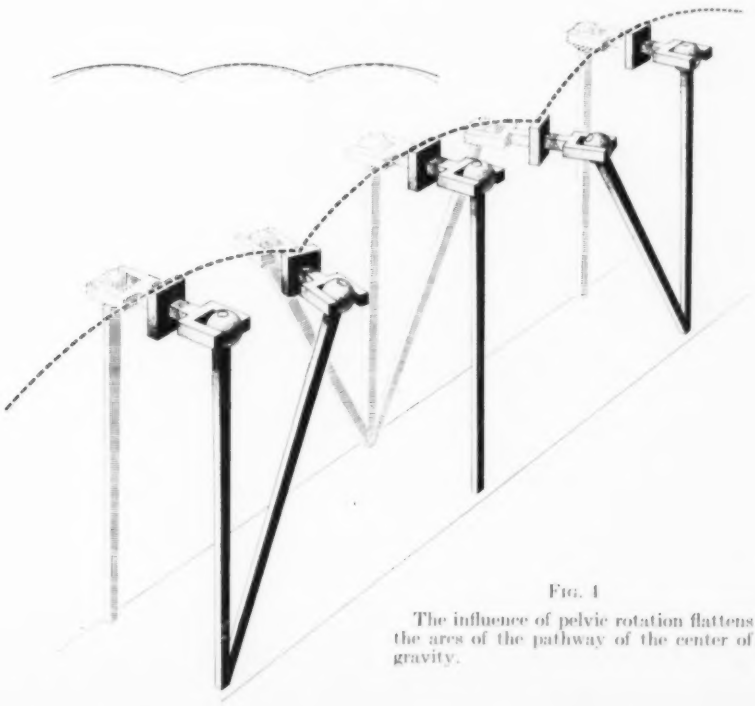


FIG. 4

The influence of pelvic rotation flattens the arcs of the pathway of the center of gravity.

ankle, or knee mechanisms but are articulated at the equivalent of a hip joint. This permits flexion and extension only (Fig. 3). In such a system quasilocomotion would produce something analogous to the process of stepping-off distances with a pair of compasses or dividers. The pathway of the center of gravity of the system in forward translation would be a series of intersecting arcs. The radius of these arcs would be equal to the length of the levers representing the extremities and, with each step, the angular rotation at the hip in flexion would equal that in extension. Locomotion of this type might be imitated, but imperfectly, by walking on the heels with the knee fixed in extension.

The energy cost to a person using the compass gait would be exceedingly high. In proportional terms of the average human stature and the length of stride, the center of gravity of the body would have to be elevated approximately three and three-quarter inches, which is double the normal vertical displacement. At the point of intersection of the arcs, the abrupt change in direction of the forward acceleration would require the application of force of considerable magnitude. Nonetheless it is from a consideration of such a simple model that the determinants of locomotion can be followed.

The First Determinant: Pelvic Rotation

In normal level walking, the pelvis rotates alternately to the right and to the left, relative to the line of progression. At the customary cadence and stride of average persons, the magnitude of this rotation is approximately 4 degrees on either side of the central axis, or a total of some 8 degrees. Since the pelvis is a rigid structure, this rotation occurs alternately at each hip joint which passes from relative internal to external rotation during the stance phase.

The significance of pelvic rotation can best be appreciated by a study of our theoretical model (Fig. 4). The effects of pelvic rotation are to flatten somewhat the arc of the passage of the center of gravity in compass gait by elevating the extremities of that arc. In consequence, the angles of inflection at the intersections of successive arcs are rendered less abrupt and, at the same time, are elevated in relation to the summit. In this way, the energy cost in locomotion is greatly reduced. The loss of potential energy is more gradual, and the force required to change the direction of the center of gravity in the succeeding arc of translation is less. The angular rotation at the hip in flexion and extension is reduced, and the energy required for the internal oscillation of the member is conserved.

The Second Determinant: Pelvic Tilt

In normal locomotion the pelvis is tilted or lists downward relative to the horizontal plane on the side opposite to that of the weight-bearing limb (positive Trendelenburg). The alternate angular displacement is on the average 5 degrees. The displacement occurs at the hip joint producing an equivalent relative adduction of the extremity in the stance phase and relative abduction of the extremity in the swing phase of the cycle. To permit pelvic tilt, the knee joint of the non-weight-bearing limb must flex to allow clearance for the swing-through of that member.

The effects of pelvic tilt on the pathway of the center of gravity are evident in the experimental model (Fig. 5). As the lateral list occurs while the body is passing over the vertical supporting member, the center of gravity is lowered. Thus the summit of the arc of its translation falls and still further flattening of the pathway results. The saving of energy by the cutting of the vertical displacement of the center of gravity in half is obvious. Further energy is saved by greater reduction at the inflection of the arcs. The flexion of the knee of the limb in the swing phase likewise conserves energy by the shortening of the pendulum.

The Third Determinant: Knee Flexion in the Stance Phase

A characteristic of locomotion is the passage of the body weight over the supporting

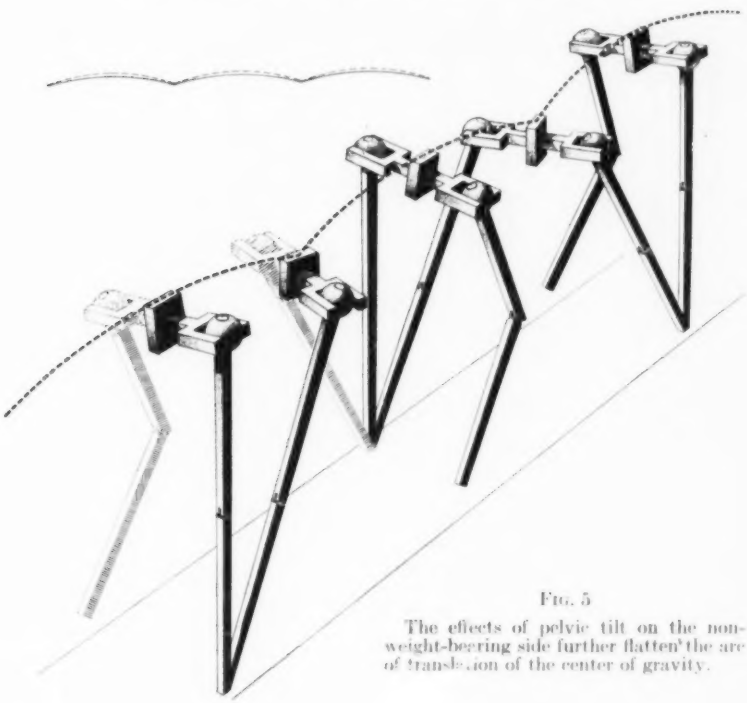


FIG. 5

The effects of pelvic tilt on the non-weight-bearing side further flatten the arc of translation of the center of gravity.

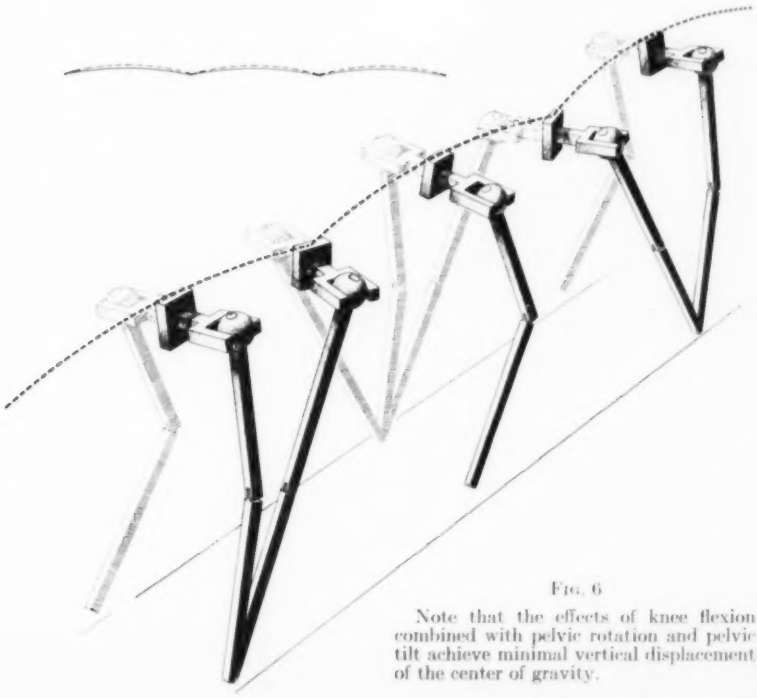


FIG. 6

Note that the effects of knee flexion combined with pelvic rotation and pelvic tilt achieve minimal vertical displacement of the center of gravity.

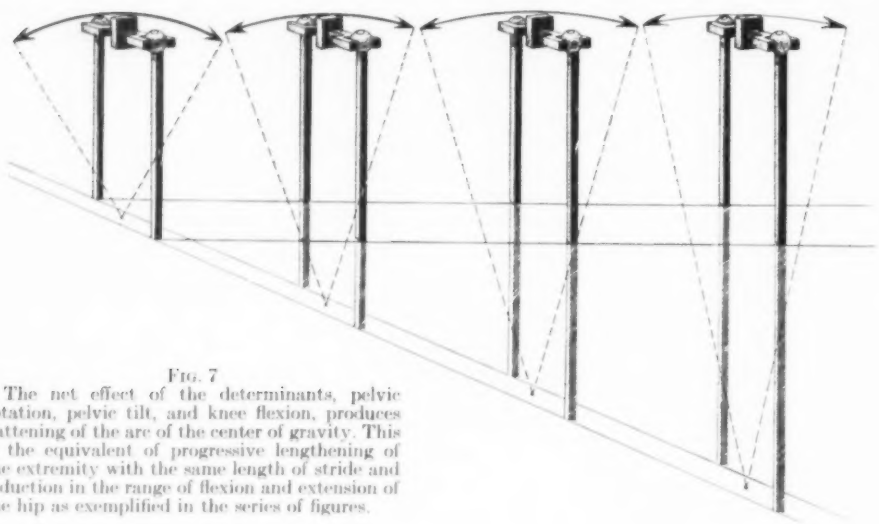


FIG. 7

The net effect of the determinants, pelvic rotation, pelvic tilt, and knee flexion, produces flattening of the arc of the center of gravity. This is the equivalent of progressive lengthening of the extremity with the same length of stride and reduction in the range of flexion and extension of the hip as exemplified in the series of figures.

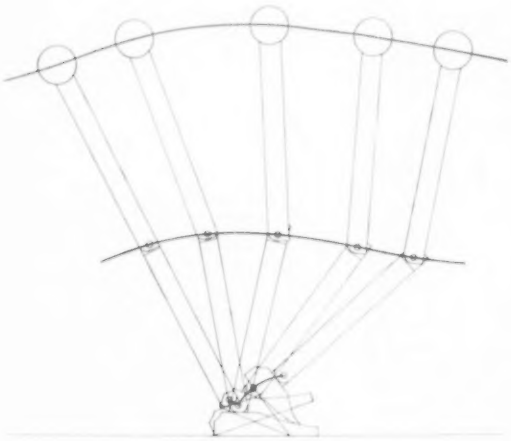


FIG. 8

The effects of the arcs of foot and knee rotation smooth out the abrupt inflexions at the intersection of the arcs of translation of the center of gravity.

extremity while its knee joint is undergoing flexion. The supporting member enters the stance phase at heel strike with the knee joint in full extension. Thereafter the knee joint begins to flex and continues to do so until the foot is flat on the ground. The average magnitude of this flexion is 15 degrees. Immediately anterior to the middle of the period of full weight-bearing, the knee joint once more passes into extension which is immediately followed by the terminal flexion of the knee. This begins simultaneously with heel rise, as the limb is at length carried into the swing phase. This period of the stance phase, occupying about 40 per cent. of the cycle, is referred to as the period of "double knee lock", since the knee is first locked in extension, unlocked by flexion, and again locked in extension prior to its final flexion.

If we examine the model (Fig. 6), the effects of walking over a flexed knee become apparent. The summit of the arc described by the passage of the center of gravity is still further lowered with the conservation of energy by reduction of its vertical displacement.

These three determinants of gait—pelvic rotation, pelvic tilt, and knee flexion—all act in the same direction by flattening the arc through which the center of gravity of the body is translated. The first—pelvic rotation—elevates the extremities of the arc, and the second and third—pelvic tilt and knee flexion—depress its summit. The net effect is the passage of the center of gravity through a segment of a circle, the radius of which is two and two-tenths longer than the length of the lower extremity (Fig. 7). The relative lengthening of the extremities reduces materially the range of flexion and extension at the hip

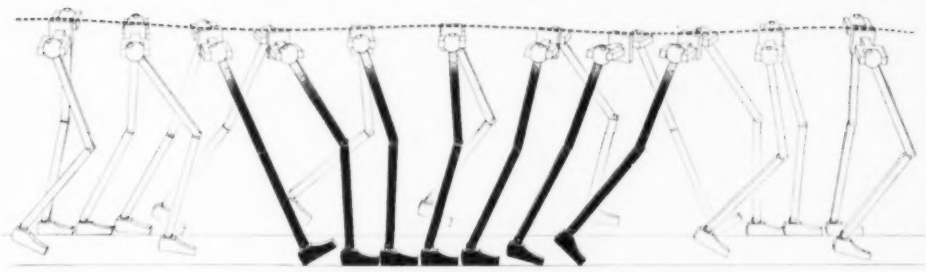


FIG. 9

The influence of the several determinants of gait on the passage of the center of gravity is seen in this "exploded" view of locomotion in which each stage of motion is equally spaced.

joint required to maintain the same length of stride. The relative elongation of the extremities plays an exceedingly important role in permitting increased velocities of gait at slight increases in energy cost, since greater velocities of locomotion are achieved by the lengthening of the stride rather than by increases in cadence.

The Fourth and Fifth Determinants: Foot and Knee Mechanisms

In the discussion of the fourth and fifth determinants of locomotion, we are concerned with the smoothing out of the pathway of the center of gravity in the plane of progression at the point of intersection of its arcs. Accurate recordings of the phase relationships of the angular displacements at the ankle, foot, and knee show that their motions are intimately related. Two intersecting arcs of rotation are established at the foot during the stance phase (Fig. 8). The first arc occurs at heel contact and is described by rotation of the ankle about a radius formed by the heel. The second arc is made by the rotation of the foot about a center established at the fore part of the foot in association with heel rise. At heel contact the foot is dorsiflexed and the knee joint is fully extended, so that the extremity is at its maximum length and the center of gravity has reached its lowest point of downward displacement. Rapid plantar flexion of the foot, associated with the initiation of knee flexion, maintains the center of gravity with its forward progression at approximately the same level for some time, thus flattening and slightly reversing the curvature at the commencement of its arc of translation. The termination of this arc is similarly flattened and slightly reversed by flexion of the second knee associated with heel rise. The effects of the rotations at the foot on the displacement pattern of the knee and the center of gravity are illustrated in Figure 8. The obliteration of the abrupt inflexions at the point of intersection of the arcs of translation of the center of gravity smooths the gait by establishing a sinusoidal pathway for its progression with a great reduction of energy cost. The translation of the center of gravity in the plane of progression is illustrated in an "exploded" view (Fig. 9).

The Sixth Determinant: Lateral Displacement of the Pelvis

As has been mentioned, the center of gravity of the body is displaced laterally over the weight-bearing extremity twice during the cycle of motion. This displacement is produced by the horizontal shift of the pelvis or by relative adduction at the hip. If the extremities were parallel to one another, the amount of this displacement would necessarily be half the interval between the axes of the hip joints, that is, approximately three inches (Fig. 10). Excessive lateral displacement is corrected by the existence of the tibiofemoral angle (Fig. 11) which, together with relative adduction at the hip, reduces the displacement to about one and three-quarter inches so that it approximates that of the vertical displacement. Thus the deviation of the center of gravity is almost symmetrical in both horizontal and vertical planes. Together, these deviations of the center of gravity

FIG. 10

Fig. 10: If the limbs were parallel, there would be excessive lateral displacement of the center of gravity.

FIG. 11

Fig. 11: Through the influence of a tibiofemoral angle and of adduction at the hip joint, excessive lateral displacement is corrected.

FIG. 12

The sum of the effects of the several determinants on the pathway of the center of gravity is viewed in true phase relationship.

contribute to the establishment in the plane of progression of the spiral of approximately equal axes and add smoothness to the gait, since all sharp inflexions are obliterated and are replaced by a sinusoidal curve. The sum of these factors is illustrated in true phase relationship in Figure 12.

THE CLINICAL EXAMINATION OF GAIT

Individual variations in locomotion are due to exaggerations in one or another of these several determinants. Owing to the interaction between the various factors, exaggerations in the range of one determinant are compensated for by reductions in another, so that the final pathway of the center of gravity remains essentially the same in that it is the most economical to maintain. Even gross pathological disturbances of the limbs have little influence on the fundamental pattern, since the loss of one function is frequently well compensated for by the exaggeration of another. Therefore, in the clinical examination of disorders of gait, the attention should be focused serially on the six determinants already described, and the exaggerations and losses in their range should be noted. In this way even minor disturbances of gait may be readily assessed.

Evaluation of Pathological Gait: Energy Levels

Before pathological gait is considered, something should be said concerning the energy levels during locomotion. In order to avoid lengthy mathematical formulation, qualitative terms will be largely employed. The energy level of a body is the sum of its potential and kinetic energies. If no work is done, the energy level is constant, as in the classical example of a simple pendulum where the loss of potential energy is exactly compensated for by the gain in kinetic energy. When the energy level is not constant, then work must be done in order to produce the change in energy level. In the computing of the energy levels of the different segments of the lower extremity, it is found that the levels are not constant. The difference is a measure of the work done by the muscles at the joints. The net result is the forward displacement of the body, but a large portion of the energy is dissipated in the rotations of the segments. These effects are referred to as the output and input of energy respectively.

From studies of the energy levels, it has been established that the output of the ankle and hip is considerably greater than the input; therefore, most of the energy required for level walking is provided by the muscles acting on these joints. In the case of the knee joint, the output is so much less than the input that this joint predominantly absorbs energy. However, the knee decreases the vertical motion of the body by flexion; and, although energy is dissipated in the process, the overall energy requirement is less than would be necessary in walking over a rigid knee. Additional energy is absorbed by the knee to decelerate the leg and foot during the swing phase. Nonetheless, not all of the energy absorbed by the knee is lost. A considerable portion is stored and is returned to the system in the later part of the swing phase by imparting continued forward acceleration to the body at the time when most of its potential energy is lost. Thus locomotion is not only due to the "push" of the member in support but also to the "pull" of the deceleration at the swinging knee.

The energy expended during straight and level walking at a constant cadence is divided approximately equally between the production of rhythmic oscillations of the legs and the elevation and depression of the center of gravity of the body. If the human mechanism were a truly efficient machine, the kinetic energy in the system would be converted into potential energy and would be stored until it is required to initiate movement in one or more of the segments of the body. However, since the muscles, when stimulated, expend energy both during contraction and elongation, energy storage is never complete or recoverable. There is evidence, however, that under certain specific and rigid situations, energy storage does occur in the muscular system and perhaps as much as 40 per cent. of

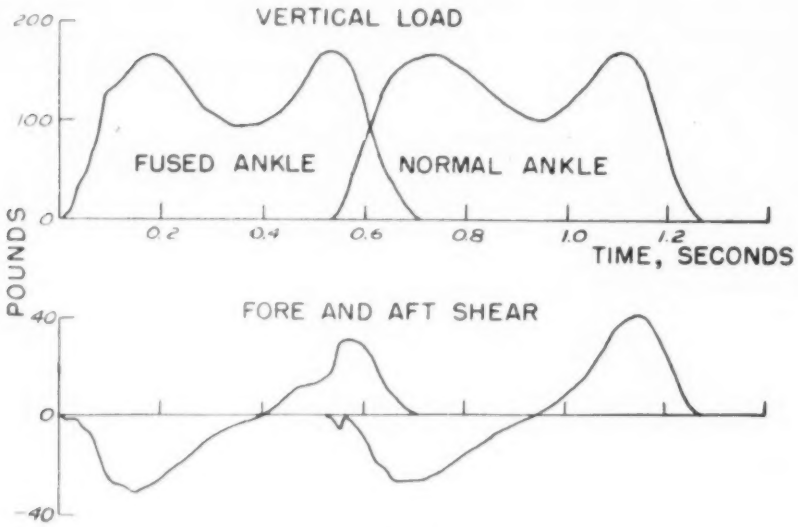


FIG. 13

Fig. 13: The vertical acceleration of the body of a person with panarthrodesis of one foot is shown. There is no appreciable difference between records of the fused ankle and the normal ankle (upper figure). The lower figure illustrates that the fore and aft shears are not altered.

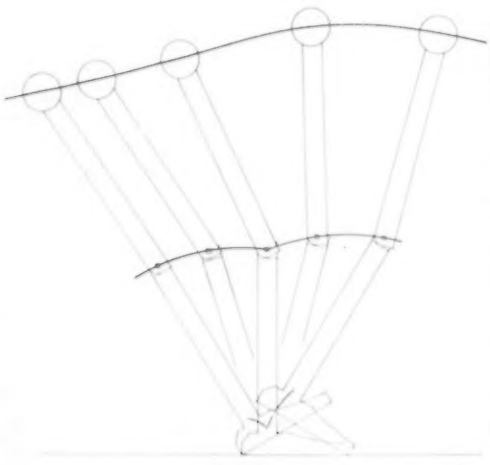


FIG. 14

Fig. 14: The abrupt inflexion in the arcs of motion at the fused ankle is transmitted to the knee joint which by excessive flexion maintains the smoothness of the path of translation of the center of gravity.

the energy put into the locomotor mechanism is recoverable. The factors which permit this energy storage and recovery will not be discussed here, but they involve the precise timing of the muscle contraction to the displacements of the moving segments, the limiting of the muscle contraction to very brief periods of activity, and the action of two joint muscles.

As the center of gravity of the body is displaced through its sinusoidal pathway of low amplitude, energy is expended during its elevation, and only a portion of this energy is recovered on its descent. The net result is a continual expenditure of energy. The magnitude of this expenditure is qualitatively appreciated by the common experience that walking up a slight grade is much more fatiguing than walking on the level, whereas walking down a gentle slope is still easier. A descending grade of approximately 4 per cent. requires little or no elevation of the body against the pull of gravity.

With the loss of one of the major determinants as a result of injury or disease, the remaining mechanisms will compensate within their ability to produce an over-all displacement of the center of gravity of the body through a sinusoidal path of low amplitude, since this requires the minimal expenditure of energy. That this is true is confirmed by an analysis of pathological gait.

The Force Plate

A ready means is available for the determining of the vertical displacement of the center of gravity of the body through the use of a force plate. A force plate is a device for measuring the ground reactions, including torque, during locomotion. Essentially the apparatus consists of a heavy metal plate which is rigidly supported by four metal columns to which are bonded a series of opposing pairs of strain gages (some fifty in all). The deformations in the x, y, and z coordinates, as well as torque, are measured by balanced bridge circuits and are recorded on an oscillograph. In operation, two such force plates are employed; the subject stepping, in the course of walking, first on one, then on the other plate. These are set flush with the walkway. In essence, the apparatus acts as an inertialess scale of great sensitivity. The force plate records directly the vertical accelerations. From these measured accelerations, it is easy to calculate the displacement of the center of gravity of the body by geometric integration. Furthermore, since the force plate measures accelerations, it is exceedingly sensitive to any changes in the normal displacement pattern of the body as a whole and is more accurate than photographic methods for the determination of sudden deviations of the center of gravity of the body caused by alterations in acceleration. The force plate, therefore, becomes a very useful instrument for the study of pathological locomotion and for the evaluation of the degree of compensation which has occurred following the loss of one or more of the major constituents of the lower extremity. Minor changes in the displacement pattern are amplified when they are recorded as changes in vertical acceleration.

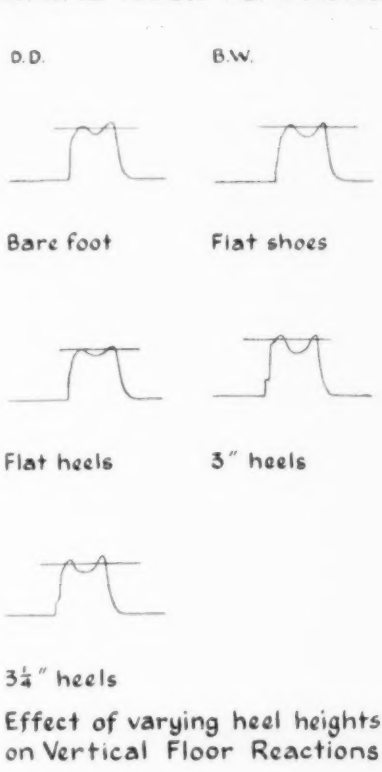
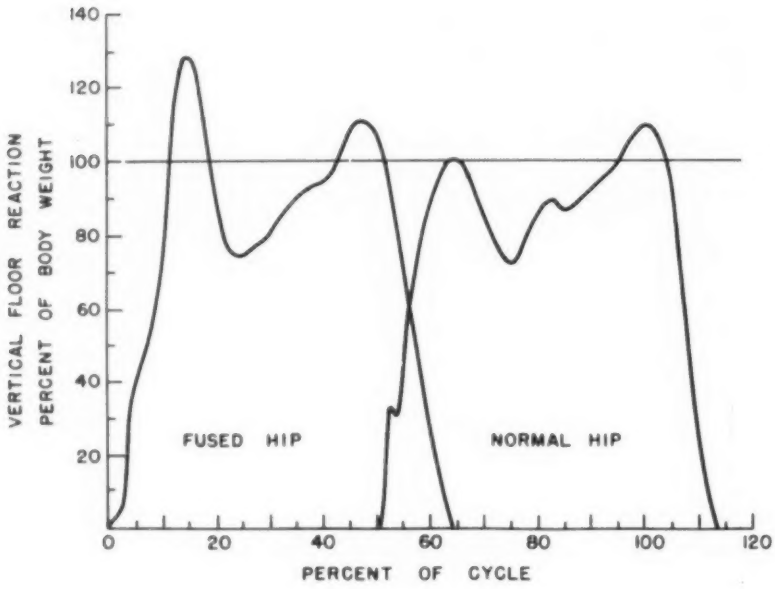


FIG. 15

Varying heel heights have little effect on vertical floor reactions, indicating a smooth translation of the center of gravity.

PATHOLOGICAL GAIT

When a person with a panarthrodesis of the ankle and subtalar joints walks, minor changes in the displacement pattern of the knee and hip may be noted. These small angular changes in the knee and hip compensate for the functions lost in the foot and ankle. The degree of compensation may be measured by recording the vertical accelerations of the force plate. In the force-plate record presented, the compensation is excellent; the only abnormality is the shock wave noted during the transition of body weight from the sound to the arthrodesed foot (Fig. 13). The pathway of the center of gravity of the body is normal and is accomplished by exaggerating the initial knee bend on the side of the arthrodesed joints. Because of the fixed ankle, the displacement of the knee joint is over two intersecting arcs, the centers of which are located at the heel and ball of the foot. However, an exaggeration of the initial knee flexion prevents the discontinuity of the curve of knee displacement from being transmitted to the trunk and maintains the



VERTICAL FLOOR REACTION FOR SUBJECT WITH FUSED HIP

FIG. 16

The difference in the floor reactions in the presence of a fused hip is shown. These abnormalities are reflected on the normal side and are indicative of the attempt to compensate at the normal hip for the loss of motion on the affected side.

normal displacement pattern of the center of gravity of the body (Fig. 14). Thus the complete loss of the foot and ankle mechanism has been completely compensated for by slight modifications in the behavior of the knee and hip with retention of the normal pattern of displacement of the center of gravity of the body.

A similar compensatory mechanism is well depicted in the change in gait seen in women while they are walking in shoes with various heights of heels. In low heels, the angular displacement of the various segments of the lower extremity are similar in both sexes. However, high heels decrease the contributions of the foot to the integrated whole and this loss is made up by modifications in the remaining constituents, namely, the pelvis, hips, and knees. The initial knee flexion is increased and the pelvic tilt and rotation are exaggerated, producing the characteristic gait which is familiar to all. This is, however, not merely an affected gait, since the force-plate records show that in this gait similar vertical accelerations are achieved, whether the person is in high or low heels (Fig. 15). The exaggerated movements of the pelvis and the increased hip and knee flexion are compensatory motions to offset the loss of the foot mechanism caused by the wearing of high heels, with the result that a normal pathway of displacement of the center of gravity of the body is maintained.

When the knee is immobilized, its important contribution to the orderly and harmonious arrangement of the segments of the lower extremity obviously is lost. The limp which characterizes a patient with a stiff knee requires no detailed description, but certain of the compensatory movements in the remaining normal segments should be pointed out. To gain clearance for the foot, excessive elevation of the pelvis on the affected side

is necessary, or an increase in the heel rise is required on the normal side. However, in spite of these deviations from what are considered as normal bodily motions, the center of gravity of the body retains a remarkably constant and nearly normal path of vertical displacement as noted from the force-plate records. This is particularly true if flexion at the knee of from 15 to 20 degrees is preserved at the time of its fixation.

The mechanisms of the lower extremity apparently are able to compensate reasonably well for the stiff knee as far as the maintenance of the normal pathway of the center of gravity of the body and the minimizing of the energy loss necessary for external work. However, the energy necessary to initiate the swing phase on the side of the stiff knee is increased to almost three times that of the normal. The flexion of the knee and, to a lesser extent, the flexion of the hip, which occurs late in the double weight-bearing phase and early in the swing phase of walking, is produced partly by the upward thrust imparted to the leg by plantar flexion of the foot and partly by the flexor muscles of the hip, the latter contributing approximately one third and the former, approximately two thirds. Early flexion of the knee at the initiation of the swing phase is important, since it converts the leg into a double pendulum and thus decreases the moment of inertia of the whole lower extremity. This in turn decreases the force requirement of the flexors of the hip. Fixation of the knee suppresses this mechanism and requires the hip flexors alone to initiate the swing phase. This demands that a force be exerted by the hip flexors that is several times greater than the normal as may be observed by the hesitancy at the commencement of the swing phase in the gait of a person with an arthrodesed knee.

The importance of the knee joint in minimizing the energy requirements in locomotion should be emphasized. The knee contributes little toward the propulsion of the body through space, but the knee joint does function to reduce the energy necessary to initiate the swing phase and to smooth out the path of the center of gravity. Immobilization of the knee by arthrodesis, casts, or long braces leads to almost tripling the energy required to start the swing phase of the involved limb. A vivid example of the role played by the knee joint in human locomotion is provided by the experience gained in the study of prostheses for above-the-knee amputees. Much effort has been expended by the Advisory Committee on Artificial Limbs of the National Research Council to develop mechanical and hydraulic devices to be incorporated into the prosthetic knee joints. All of these mechanisms were intended to limit the heel rise at the beginning of the swing phase and to improve the appearance of the amputee's gait. However, the increased resistance to flexion and extension in the knee joints, which the devices provide, requires the amputee to expend more energy. (The devices were, therefore, disliked by the amputee.) Many an amputee would leave the limb shop with a well functioning device and an improved appearance in his gait, only to return at a later time with a free-swinging knee joint with its resultant abnormal heel rise. With a wrench and a screw driver the amputee had managed to render the mechanism functionless so that the energy cost was lowered at the expense of the aesthetic appearance of his gait.

The exponents of pylons for above-the-knee amputees realize the importance of the knee joint in decreasing the amount of energy required to initiate the swing phase on the amputated side when they insist that a pylon should be as light as possible in weight. The reduction of the weight placed distally in the extremity does not appreciably increase the moment of inertia over that of the stump itself and thus requires minimal effort to start the swing phase. In the conventional prosthesis, the conversion of the lower extremity into a double pendulum by the incorporation of a free knee joint obviates, to a certain degree, this difficulty.

The relatively inconspicuous limp caused by an arthrodesed hip in good functional position can easily be detected by abnormalities in the vertical floor reactions (Fig. 16). The remaining normal segments of the inferior extremity are able to compensate only partially for the loss of the hip joint. It will be recalled that pelvic rotation and pelvic tilt

are important factors in decreasing the vertical displacement of the center of gravity of the body. At the point of maximal elevation of the center of gravity of the body, the hip joints are in mid-position with respect to rotation. From this point to the position of double weight-bearing, in which the feet are widest apart in the stride, the pelvis rotates externally about the weight-bearing hip joint. This may be expressed as internal rotation of the femur with respect to the pelvis. This movement, although of small magnitude, is of considerable importance. When the hip is affected by disease with resultant limitation of motion, it will be found that the hip will be held in external rotation during the swing phase so as to be in a position to make available during the stance phase what little internal rotation remains and to allow the pelvis to rotate in an approximately normal manner.

The loss of one of the major joints of the extremity is almost fully compensated for by exaggerated motions at other levels as studies in below-the-knee amputees clearly reveal. In such cases the vertical floor reactions indicate that the center of gravity of the body is still translated smoothly through a sinusoidal pathway at low energy cost. However, the amputee who has lost both foot and knee is unable to compensate satisfactorily and the vertical floor reactions deviate markedly from the normal pattern. Because of the minor changes in direction from the smooth sinusoidal pathway of the center of gravity, high accelerations are required which dissipate energy and make such deviations very costly. So great is the cost that, as our experience has shown, the loss of two joints in the elderly subject will inevitably shorten life from the demands upon his cardiovascular system which must supply his requirements at the usurious rate of 300 per cent.

SUMMARY

Human locomotion is a phenomenon of the most extraordinary complexity in which so great are the multitude of individual motions occurring simultaneously in the three planes of space that analysis is difficult without some unifying principle. The adoption of the concept that fundamentally locomotion is the translation of the center of gravity through space along a pathway requiring the least expenditure of energy supplies the necessary unifying principle which permits of qualitative analysis in terms of the essential determinants of gait. The six major determinants are pelvic rotation, pelvic tilt, knee and hip flexion, knee and ankle interaction, and lateral pelvic displacement. The serial observations of irregularities in these determinants provides insight into individual variation and a dynamic assessment of pathological gait. Pathological gait may be viewed as an attempt to preserve as low a level of energy consumption as possible by exaggerations of the motions at unaffected levels. Compensation is reasonably effective with the loss of one determinant of which that at the knee is the most costly. Loss of two determinants makes effective compensation impossible and the cost of locomotion in terms of energy is increased threefold with an inevitable drain upon the body economy.

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ADRENOCORTICAL RESPONSE IN OPERATIVE PROCEDURES UPON THE BONES AND JOINTS *

BY JAMES A. NICHOLAS, M.D., AND PHILIP D. WILSON, M.D., NEW YORK, N. Y.

Orthopaedic surgeons are accustomed to think of the responses of their patients to operations upon the bones and joints in terms of surgical reactions and of the success of such procedures as depending chiefly upon the perfection of operative technique and the soundness of the postoperative treatment. They give small heed to the complicated metabolic responses of the body which are set off by these operative procedures and which must to a greater or lesser extent influence their outcome. These metabolic changes are largely the result of the interplay among the hypothalamus, the pituitary, and the adrenal glands [12, 21, 23].

While these endocrinological reactions are being extensively studied by internists and general surgeons, nothing has yet appeared to show that orthopaedic surgeons are awake to their importance. Yet the field of orthopaedic surgery is an interesting one for investigation, because it is quite different from that of surgery of the abdomen and thorax. Its operative procedures are of equal severity, but are performed upon the bones or joints and, because of the slow healing of these structures, often require prolonged immobilization of the parts in plaster-of-Paris encasements or protection by traction or braces. In addition, metallic devices are frequently used for internal fixation, and plastic or metallic appliances may be inserted as artificial replacements for damaged portions of the skeleton. These differences raise questions about the metabolic responses of the body under these special conditions and their possible influence on bone healing [17]. It seemed important to try to answer them by undertaking a study of adrenocortical function following injury or operation upon the skeletal system. As Prof. F. D. Moore of Harvard stated recently in discussing a paper presented before the American Surgical Association: "We, as surgeons, are endocrinologists whether we like it or not. We must discipline our thinking, bring our terminology into harness, and keep our concepts clear as we pilot our way through these next few confusing years of increasing knowledge of surgical endocrinology."

OBJECTS OF STUDY

We set out to study the general adaptation syndrome with relation to orthopaedic surgical procedures and we tried to define our objectives in the form of questions as follows:

1. Is there any evidence of stress from prolonged immobilization or corrective plasters?

2. What are the effects upon the adrenal responses of major multiple-stage operations such as may be required in scoliosis, Pott's disease, or poliomyelitis?

3. May long-continued stress produce metabolic responses which are inimical to wound and bone healing? [9]

4. What are the effects of chronic infection such as tuberculous joint disease or chronic osteomyelitis?

5. Does the operative insertion of metallic appliances or plastic prostheses in the body create a condition of stress?

6. Do bone tumors create a condition of stress and, if so, can the demonstration of this condition be of any diagnostic significance?

7. Is there any evidence that, in cases of prolonged stress, a condition of adrenal refractoriness or depletion may develop in which hormonal replacement therapy may be indicated?

* Read at the Joint Meeting of the Orthopaedic Associations, London, July 1, 1952.

MECHANISM OF ADRENAL STIMULATION AS A RESULT OF A FRACTURE

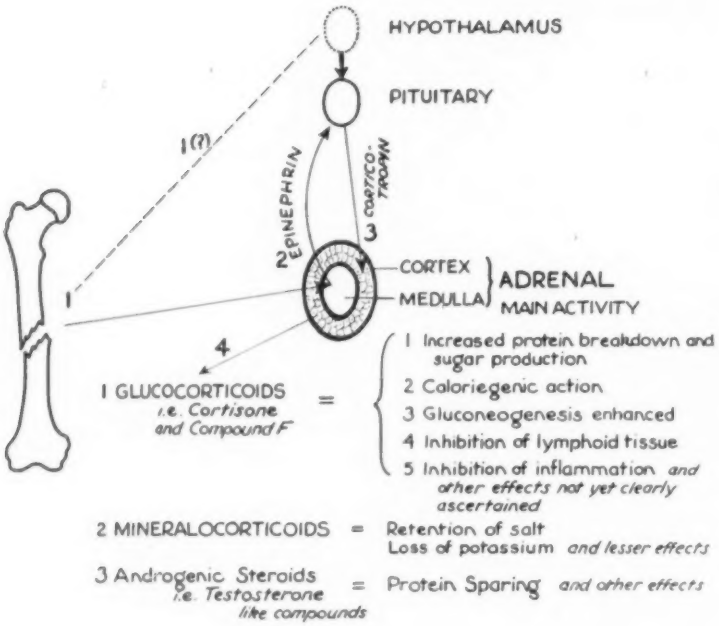

CHART I

Depicts the mechanism which is supposedly invoked following injury.

In summary, our aim was to study the departure from the normal of adrenal function following orthopaedic operations either toward hypofunction, which in the extreme is Addison's disease [4, 19] or toward hyperfunction, which may result in Cushing's syndrome [11].

THE ALARM REACTION AND ADRENOCORTICAL FUNCTION

When sudden stress is thrown upon the body by injury, such as a fracture of the femur or operative trauma, a stimulus is relayed to the pituitary, probably by way of the hypothalamus, and corticotropin (ACTH) is released. This causes adrenocortical stimulation and, as a result, steroids are produced and circulated in increased quantity throughout the body (Chart I). This "alarm reaction" is considered to initiate physiological responses for the conservation of life and to adapt the body to cope more easily with harmful influences. The long-term clinical systemic effects of the action of these corticosteroids constitute what is called the "general adaptation syndrome" [2, 3, 5, 14].

Although there are many classifications of the adrenocortical hormones, probably the simplest is their division into three categories—namely, glucocorticoids, mineralocorticoids, and androgenic steroids. Whether one type of steroid is transformed into three or more hormones, or whether three types of corticoids are separately secreted has not yet been ascertained.

The glucocorticoids, which include cortisone and compound F, exert their effects mainly upon glucose metabolism, but they also have many lesser effects. Their action is chiefly catabolic and anti-anabolic; for this reason they are of importance to the surgeon because of their effect upon elements which play a part in wound repair and bone healing. Among their effects the following have been noted [7, 11, 23]:

1. Increased gluconeogenesis (sugar production);
2. Increased breakdown of protein;

3. A calorigenic effect which provides an increased amount of energy to meet the increased metabolic requirements created by stress [6];

4. An anti-inflammatory response;

5. An antihyaluronidase effect which is believed to aid in decreasing the exudative response to trauma;

6. A drop in the level of vitamin A and vitamin C circulating in the blood stream;

7. A drop in the level of circulating eosinophils. This has been shown to be due chiefly to the action of cortisone and hydrocortisone (compound F);

8. Regression of lymphoid tissue;

9. Lesser effects on mineral metabolism.

The mineralocorticoids exert powerful effects upon electrolyte balance and especially cause sodium and chloride retention and increased potassium excretion. Little is yet known of their effects on the metabolism of calcium.

The exact role of androgenic steroids is not quite clear; their action is thought to be anabolic or anticatabolic and somewhat similar to that of testosterone.

More is known about the effects of cortisone than those of any of the other cortical steroids. It has been shown to exert powerful immunological, metabolic, and other physiological effects. Prolonged stress causes the liberation of increased quantities of cortisone and hydrocortisone (compound F) and other glucocorticoids which may exert significant effects upon the healing of wounds and of bone.

Sufficient alarm produces a general adrenocortical response. The presence of increased quantities of glucocorticoid, mineral corticoid, and androgenic steroids can be determined by various chemical analyses of different substances in the blood and urine. For example, the amounts of sodium, potassium, and chloride can be measured in the blood and urine and give an indication of the mineralocorticoid response. Determinations of blood and urinary nitrogen and sugar, together with nitrogen-balance studies, show the activity of the glucocorticoids. It is believed that measurement of the ketosteroids in the urine gives an indication of androgenic-steroid response [14] and that quantitative analysis of the oxysteroids shows the glucocorticoid response [1, 10].

To make the large number of complicated chemical determinations which would be required to follow a large number of patients through the preoperative, operative, and postoperative phases in studying adrenocortical reaction would be prohibitively time-consuming and expensive. Fortunately, an easier method is available which has been shown by Thorn, Evans, and others to be an excellent indicator of adrenocortical activity. This is the level of eosinophils circulating in the blood [16, 18, 22].

EOSINOPHIL LEVELS

When cortisone or hydrocortisone (compound F) are administered, a rapid drop occurs in the level of circulating eosinophils and the decrease bears a rough relationship to the quantity of hormone given. Of the various adrenal hormones tested, only the two mentioned above produce this result. After the hormonal effect ceases, the level of eosinophils returns to normal or temporarily above normal. The administration of twenty-five milligrams of adrenocorticotropin (ACTH) also depresses the eosinophil level, usually by at least 50 per cent. within a period of four hours. Thorn used this as a test of adrenocortical reserve and considered a response of less than 50 per cent. as indicative of dangerously lowered function.

It was observed before the turn of the century that the appearance of eosinophilia following illness often coincided with the patient's clinical improvement. Injury or operative trauma is followed by eosinopenia, which is evidently the result of excitation of the pituitary with liberation of adrenocorticotropin (ACTH) which in turn stimulates adrenal secretions. Failure to develop eosinopenia following trauma is thought to be indicative of some disorder either at the adrenal or pituitary level [21, 24]. Rud, following a study of 525

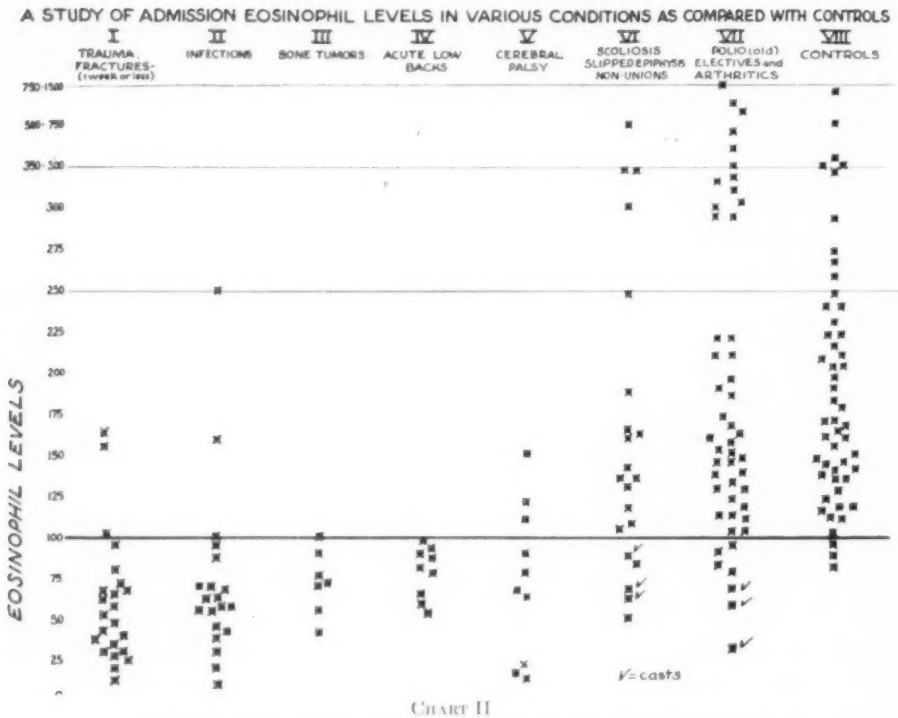

CHART II

The influence of stress can readily be seen in comparison of the columns.

subjects, noted that the eosinophil level behaved characteristically in health and mental disease.

It is recognized that this is a new field of study in which much remains to be learned, and it is also admitted that the determination of eosinophil levels is only a limited method of testing complete adrenocortical activity. Nevertheless, there is sufficient evidence in the literature to show that consecutive eosinophil counts, when done accurately and according to proper standards, may yield important information. It was because of this conclusion, reached only after careful study of the literature, and because of the ease and rapidity with which this method could be utilized frequently and consecutively in many patients, that we adopted it for study of our patients both before and following orthopaedic surgical procedures.

METHOD OF STUDY

In an attempt to eliminate common sources of error, we adhered rigidly to several specifications in our technique. We used standardized pipettes and chambers and used the same pipettes on the same patients. The stains were frequently filtered. We drew two cubic centimeters of venous blood and always counted four chambers. If a difference of over ten cells in any chamber from another was noted, the count was repeated until satisfactory spread was obtained. Since there is a slight variation in the morning and afternoon counts in the same patient, we made it a point to draw the blood at the same time each day. Also we made use of Randolph's method. Finally, the counts were made always by the same team, one physician and one technician.

A group of fifty-two control cases composed mainly of hospital personnel who were free from illness and known tension were first studied. They were divided into two groups of twenty-six each; the first group had morning counts and the second had afternoon

counts. The counts were performed on from six to eight separate days on each person and always at the same time of day. The results obtained were consistent and served to prove that our technique was accurate. To corroborate further our control study, we compared these counts with those made on a group of patients who underwent elective operations for the correction of various types of deformity which had been incurred in childhood, but who were free of disease at the time of operation. The results here were identical with those in the controls.

The material for study was made up of 125 patients suffering from various types of skeletal injury or orthopaedic disease. Serial eosinophil counts were made from admission, during and following operation, and during convalescence, often many weeks after discharge from the hospital. Thorn tests were often carried out before operation and also at different stages of recovery when indicated. The patient's clinical behavior was carefully observed preoperatively, during operation, and postoperatively. A rating system was devised by means of which the patient's vital signs and clinical course could be evaluated. These were recorded objectively, as were the amounts of sedations, medication, and other supportive treatment. Wound healing was observed and all complications were recorded, such as sloughing, separation, drainage, or marginal necrosis. The wounds were not rated as complicated unless their treatment prolonged the patient's hospital stay. Wound complications which occurred within plaster casings, where pressure might have been a factor or where an obvious physical element accounted for it, were not included.

RESULTS OF STUDY

Comparison of Eosinophil Levels of Newly Admitted Patients with Those of Normal Controls

The results of a study of admission eosinophil levels in various orthopaedic conditions compared with a group of normal controls are shown in Chart II. As we recognized that there may be considerable variability in the eosinophil counts at different times, serial counts were done on different days when possible and many of the patients had repeated counts. It was observed that low counts varied only slightly, while counts above 200 varied considerably. Many showed a range of only plus or minus 10 per cent. of the initial level. This indicated a marked consistency of eosinophil levels in our series.

The last column on the right in Chart II indicates the average results in the fifty normal controls collected over a twenty-month period. The counts ranged between 100 and 250 in 74 per cent., which is the range that Thorn considers normal. Only 6 per cent. of the counts were below 100 while 20 per cent. had counts above 250. As a result of these observations, we are inclined to feel that the upper limit of the normal range should be increased to 300 or 350. The fluctuation of counts did not exceed plus or minus 20 per cent. in 90 per cent. of the cases, while in 65 per cent. it did not vary over plus or minus 10 per cent.

When the other groups of cases shown in Chart II are studied, some interesting differences can be noted in comparison with the control group. Patients with recent fractures of bone, infections, or acute low-back pain and tumors with a few exceptions showed eosinopenia. Patients who were admitted for elective surgical procedures, such as correction of deformity in poliomyelitis or scoliosis, had counts which compared with the control group. In Groups VI and VII of the twelve counts which averaged below 100, plaster casings were being worn by six of the patients; this may be considered as an adequate cause of stress. Cerebral-palsy patients generally had low counts. Only six patients with fractures or infections showed eosinophil counts over 100. In three of these the Thorn test was below 50 per cent., indicating adrenal refractoriness.

Our findings on this part of the study therefore substantially agreed with Thorn's finding that 100 is the lower limit of normal; the upper limit, however, is probably higher than he thought, perhaps even up to 350. It appears that the eosinophil level can serve as a fairly reliable method of showing response to stress and adrenal stimulation; hence it

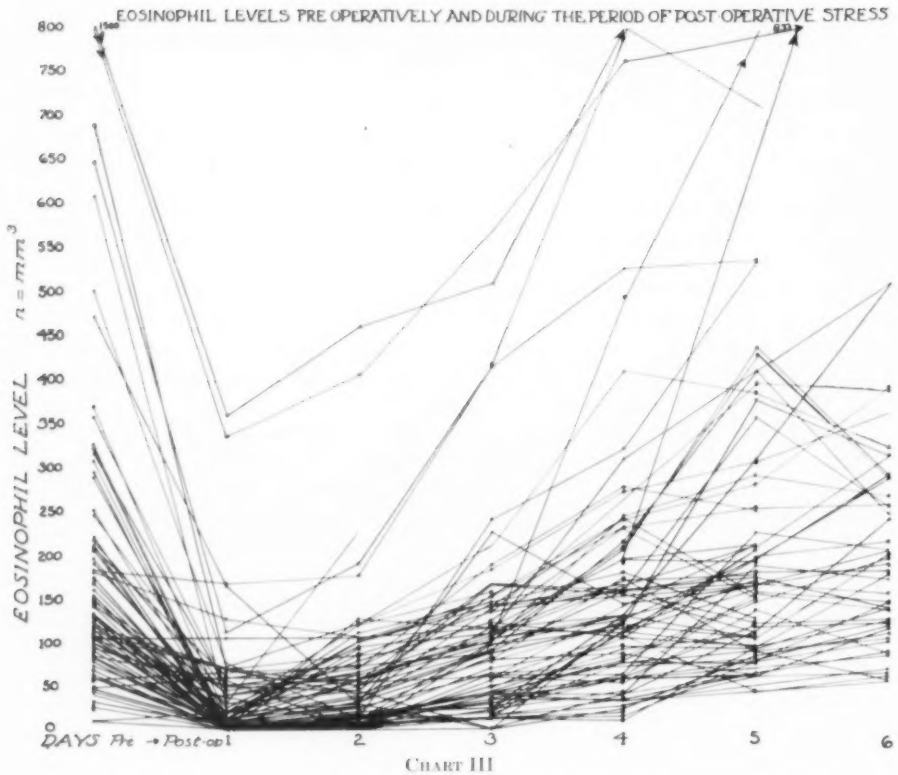

CHART III

Showing the sharp postoperative drop within twenty-four hours and the subsequent pattern.

can serve as a diagnostic and prognostic aid in conditions producing prolonged eosinopenia, such as bone and joint infections, hematomata, or in acutely painful states, such as acute low-back pain and herniated discs. By the same token it may help to differentiate the malingerer from the true sufferer in medicolegal and other cases where this question may be raised.

It is of interest to note that in a case of extensive caseous tuberculosis of the knee in which the sedimentation rate of the erythrocytes was within normal limits the eosinophil count was depressed to 50 and was therefore a truer indication of active disease than the former. Following knee fusion and into convalescence, the eosinophil count rose and leveled off at 400. In other cases we have noted that a rising eosinophil count parallels a falling sedimentation rate.

Behavior of Eosinophil Levels after Surgery or Trauma

We have broken down our study of these consecutive eosinophil counts into two periods: the first, the stress period which represents the first five days after injury or surgery, and the second, the convalescent period.

The counts during the stress period are shown in Chart III and it can be seen that the changes are profound and almost uniform. Marked eosinopenia lasting from seventy-two to ninety-six hours is followed by rapid rise to normal levels. This indicates strong adrenal-cortical stimulation as a normal result of stress. Failure to respond in this manner would indicate either failure of normal stimulation or impairment of adrenal function.

During the convalescent period the counts showed considerable variability and it

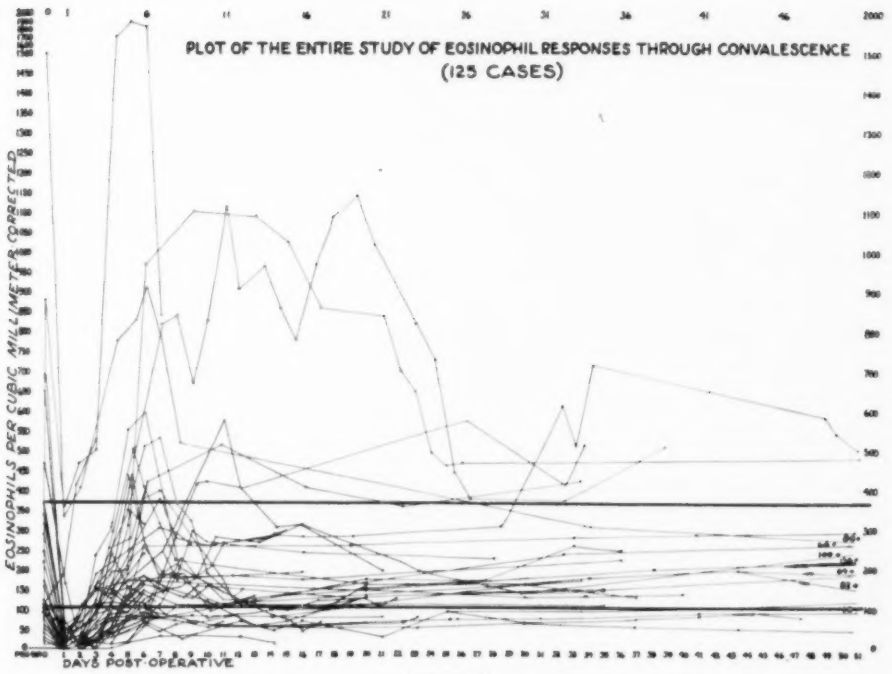
PLOT OF THE ENTIRE STUDY OF EOSINOPHIL RESPONSES THROUGH CONVALESCENCE
(125 CASES)
EOSINOPHILS PER CUBIC MILLIMETER CORRECTED
DAYS POST-OPERATIVE

CHART IV

Although in most of the cases there is a return to preoperative levels, some cases are eosinopenic and others are eosinophilic. Cases with hematopoietic or other stimulant therapy are not depicted.

was difficult to draw conclusions. Nevertheless, two types of variation were noted which are worthy of further investigation (Chart IV). It was noted that high levels of eosinophilia developed in some patients while severe eosinopenia developed in others. These cases will be considered later in this paper.

It should be noted that all patients were eliminated from this part of the study in whom sensitivity to drugs existed or to whom hematopoietic stimulants had been administered, such as liver, folic acid, or iron, as these are known to produce eosinophilia through their stimulating action on the bone marrow.

Eosinophil Level with Relation to Clinical Course of Patient

Clinical observation of the patients from day to day revealed that rising eosinophil counts following periods of stress corresponded with clinical improvement. The patients felt better, their appetite improved, fever declined, urinary output increased, and there was lessened need for analgesics. It was noted in the postoperative course of most patients that, following a severe depression lasting two to three days, the eosinophil level rebounded rapidly to normal and even above normal, but eventually returned to the normal preoperative level.

Low counts persisted in patients who were ill following operation. There were two exceptions. These patients, although quite ill, showed eosinophilia. In one of these patients bronchopneumonia developed forty-eight hours after operation, with elevated temperature. A Thorn test was carried out with negative response and was interpreted as indicating adrenal refractoriness. She was given cortisone in therapeutic doses for five days. After thirty-six hours the fever subsided and her reactions became normal. This test, however, is inconclusive, because at the same time she was treated with antibiotics; and it is more likely that she improved as a result of this treatment rather than as a result of cortisone.

STUDY OF THE NUMBER OF DAYS TAKEN FOR EOSINOPHIL LEVEL TO RETURN TO 50 PERCENT OF THE PRE-OPERATIVE LEVEL AFTER SURGERY

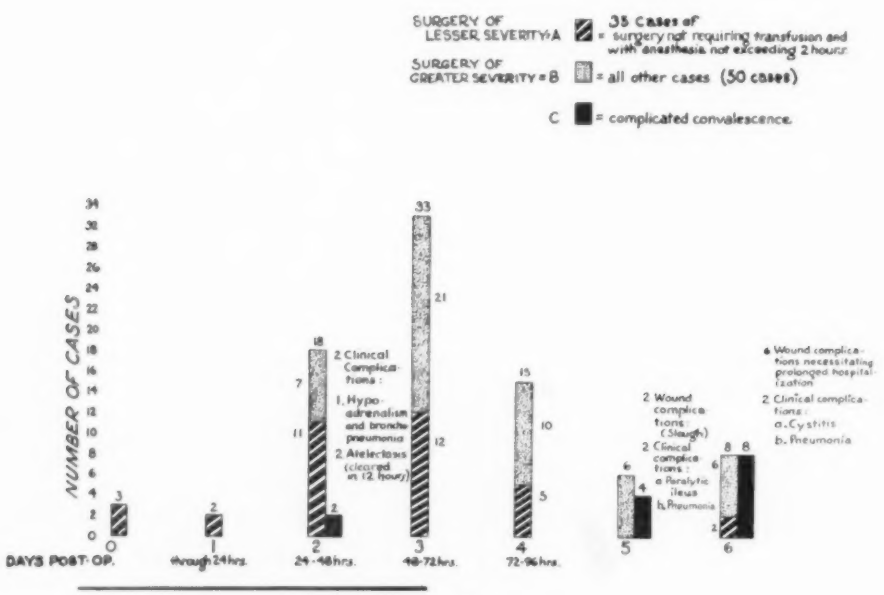
SURGERY OF LESSER SEVERITY=A
35 cases of = surgery not requiring transfusion and with anaesthesia not exceeding 2 hours
SURGERY OF GREATER SEVERITY = B
= all other cases (50 cases)
C = complicated convalescence.
NUMBER OF CASES
DAYS POST-OP.
0
1 through 24 hrs.
2 24-48 hrs.
3 48-72 hrs.
4 72-96 hrs.
5
6
2 Clinical Complications: 1. Hypoadrenalism and bronchopneumonia 2. Atelectasis (cleared in 12 hours)
2 Wound complications (Slough)
2 Clinical complications: a. Paralytic ileus b. Pneumonia
6 Wound complications necessitating prolonged hospitalization
2 Clinical complications: a. Cystitis b. Pneumonia

CHART V

Illustrates how the greater the intensity of surgery, the longer the eosinopenia, as well as the rising incidence of complications with prolonged eosinopenia.

We do think that the administration of cortisone contributed to her recovery. In the second patient high eosinophilia developed one month postoperatively. This corresponded with the development of a draining sinus. Her Thorn test too was negative at this time, although she had shown an excellent response when it was done preoperatively.

The rebound phenomenon of the eosinophils generally did not occur when postoperative complications developed. In these cases, with the exceptions noted above, the counts remained depressed until the complicating condition was relieved. A study of the cases in which the eosinophil counts were depressed to a level of less than 50 per cent. of the preoperative level for a longer than average period of days is shown in Chart V. An effort was made to divide these cases into two classes according to the severity of their operations. Procedures of lesser severity were considered to be those requiring less than two hours of anaesthesia and no blood replacement. Those of greater severity either required more than two hours of anaesthesia, or blood transfusion, or both. From this graph one may note that the greater the severity of the surgery, usually, the longer the eosinopenia. Nevertheless the phenomenon of rebound was remarkably consistent.

It is of great interest to note that complications had occurred in all of the eight patients in whom the count remained depressed to below 50 per cent. of the preoperative level for six days and in four of the six patients in whom it was depressed for five days. Of these complications, four had been recognized early and included two pneumonias, one cystitis, and one paralytic ileus. The other eight patients had complications of wound healing such as skin slough, infection, hematoma, or wound separation. In six patients the wound complication was severe and prolonged the patient's hospital stay. In none of these cases was the wound complication discovered until later, at the time the sutures were removed. In two cases the complication was not evident until the eighteenth and

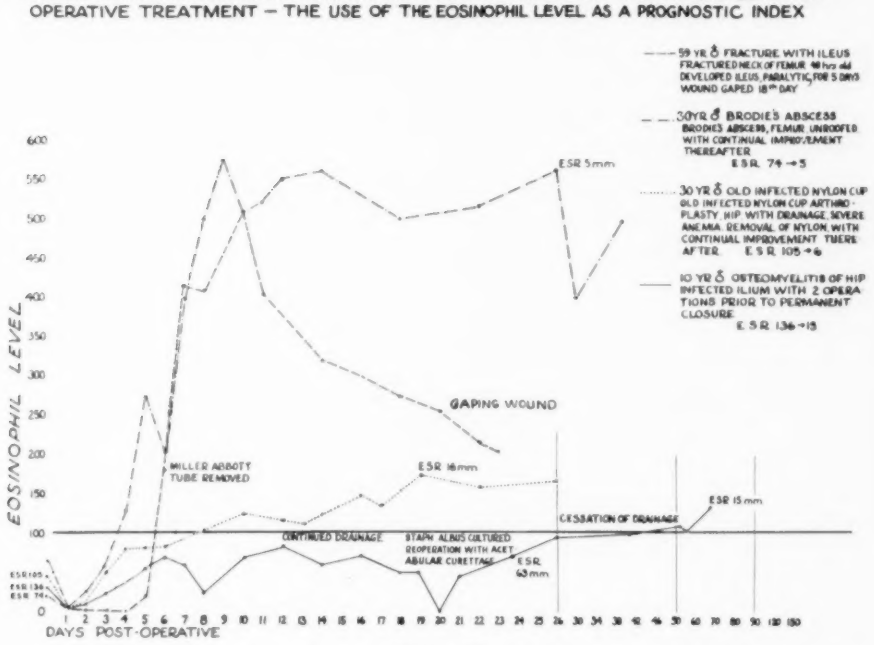
GRAPH DEPICTING FOUR DIFFERENT PATIENTS WITH INITIAL EOSINOPENIA – THEIR RESPONSE AFTER OPERATIVE TREATMENT – THE USE OF THE EOSINOPHIL LEVEL AS A PROGNOSTIC INDEX
59 YR ♂ FRACTURE WITH ILEUS
FRACTURED NECK OF FEMUR 48 hrs old
DEVELOPED ILEUS, PARALYTIC, FOR 5 DAYS
WOUND GAPED 18th DAY
30 YR ♂ BRODIE'S ABSCESS
BRODIE'S ABSCESS, FEMUR UNROOFED
WITH CONTINUAL IMPROVEMENT
THEREAFTER
E.S.R. 74 → 5
30 YR ♂ OLD INFECTED NYLON CUP
OLD INFECTED NYLON CUP ARTHRO-
PLASTY, HIP WITH DRAINAGE, SEVERE
ANEMIA. REMOVAL OF NYLON WITH
CONTINUAL IMPROVEMENT THERE-
AFTER. E.S.R. 105 → 6
10 YR ♂ OSTEOMYELITIS OF HIP
INFECTED ILIUM WITH 2 OPERA-
TIONS PRIOR TO PERMANENT
CLOSURE
E.S.R. 136 → 15
EOSINOPHIL LEVEL
DAYS POST-OPERATIVE
ESR 5mm
GAPING WOUND
MILLER ABBOTT TUBE REMOVED
ESR 16mm
CESSATION OF DRAINAGE
ESR 15 mm
CONTINUED DRAINAGE
STAPH. ALBUS CULTURED
REOPERATION WITH ACET.
ABULAR CURETTAGE
ESR 63mm
ESR 105 →
ESR 136 →
ESR 74 →

CHART VI

Illustrating how removal of stress releases the patient from eosinopenia.

twenty-third postoperative days. A prolonged depression of the eosinophil count following operation is, therefore, of considerable prognostic importance and certainly calls for careful and repeated check-up on the patient. It may also be argued from the frequency of wound complications in these cases that the environment for good wound healing is produced within the first three to four days following operation.

Use of the Eosinophil Level in Prognosis

In Chart VI are illustrated the consecutive eosinophil counts of four patients who showed severe eosinopenia upon admission to the hospital. The first patient had incurred fracture of the neck of the femur forty-eight hours prior to admission. She was operated upon the following day, the fracture was reduced, and a Smith-Petersen nail was inserted for fixation. Paralytic ileus developed following operation and the patient was in serious condition. A Miller-Abbott tube was inserted and she was given supportive therapy. Although she showed profound eosinopenia, the tube was removed. Vomiting recurred and it was necessary to reinsert the tube. Thirty-six hours later, after the eosinophil count had begun to rise, the tube was removed and the patient had uneventful progress.

The other three patients exhibited eosinopenia because of infection. One had a postoperative infection following nylon-cup arthroplasty of the hip and the other two had osteomyelitis. All had elevated sedimentation rates of the erythrocytes upon admission. In two of these cases, the eosinophil level rapidly rebounded to above normal upon surgical eradication of the infection. In the third case the eosinophil count remained depressed after the first operation and a second operation was later required. After recovery from this with cessation of drainage the eosinophil level rose to normal. It is particularly interesting to note that the high sedimentation rates in these patients dropped to normal as the eosinophil levels returned to normal or above normal.

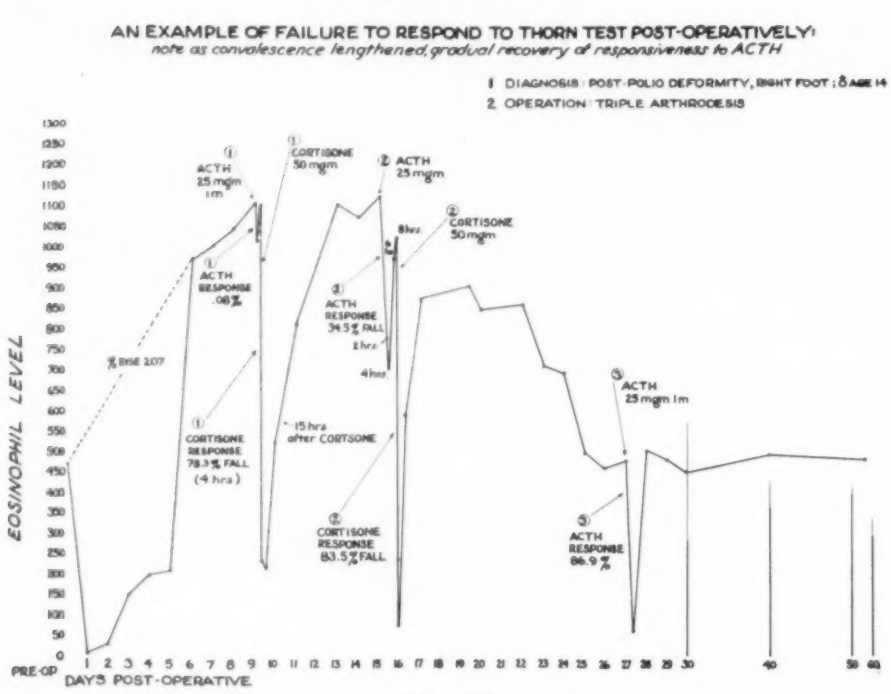
AN EXAMPLE OF FAILURE TO RESPOND TO THORN TEST POST-OPERATIVELY
note as convalescence lengthened, gradual recovery of responsiveness to ACTH
1 DIAGNOSIS: POST-POLIO DEFORMITY, RIGHT FOOT; ♂ AGE 14
2 OPERATION: TRIPLE ARTHRODESIS
EOSINOPHIL LEVEL
PRE-OP
DAYS POST-OPERATIVE
① ACTH 25 mgm im
① CORTISONE 50 mgm
② ACTH 25 mgm
② CORTISONE 50 mgm
8 hrs
① ACTH RESPONSE .08%
③ ACTH RESPONSE 34.5% FALL
2 hrs
4 hrs
% RISE 207
① CORTISONE RESPONSE 78.3% FALL (4 hrs)
15 hrs after CORTSONE
② CORTISONE RESPONSE 83.5% FALL
③ ACTH 25 mgm Im
③ ACTH RESPONSE 86.9 %

CHART VII

Showing the gradual return of responsiveness to ACTH postoperatively.

It appears from this study that the eosinophil level may be of use as a prognostic guide in recovery from any stressful situation. Patients with acute fractures of the hip consistently show eosinopenia and evidence of stress. In aged patients who are not in good physical condition, this seems to offer a good argument for early operation and fixation of the fracture in order to relieve stress. More evidence bearing on this point will be accumulated.

Evaluation of Results of the Thorn Test

As was stated previously, the administration of twenty-five milligrams of adrenocorticotropic hormone (ACTH) will ordinarily depress the eosinophil level by at least 50 per cent. within four hours. Thorn considered this to be a good test of adrenocortical function and thought that a response of less than 50 per cent. was indicative of lessened adrenocortical reserve. This has come to be known as the "Thorn test" and it has been used extensively for experimental purposes. We were also interested in studying this reaction to determine whether or not it was of valuable prognostic importance in operative cases.

Twenty patients were subjected preoperatively to the Thorn test. Of these, two showed no change in the eosinophil level, four showed a drop of less than 50 per cent., and the remaining fourteen showed the predicted response of over 50 per cent. Of the six patients who showed poor responses, only one had a postoperative complication. This was the patient mentioned previously who incurred pneumonia. She was subjected to a second Thorn test with negative result, whereupon she was given cortisone. Concomitantly, she was treated also with antibiotics and recovered. She showed eosinophilia at a time of stress and we believe she had lowered adrenocortical function. The other patients progressed through operation and convalescence without incident.

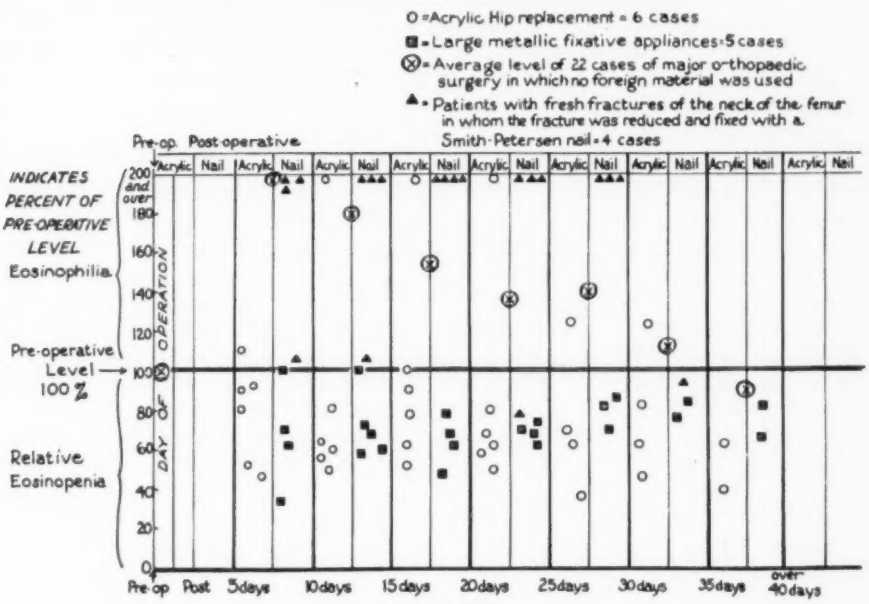
GRAPH OF EOSINOPHIL LEVELS IN PATIENTS WITH ACRYLIC HIP PROSTHESES (6 CASES) OR METALLIC FIXATIVE APPLIANCES (5 CASES)
O = Acrylic Hip replacement = 6 cases
■ = Large metallic fixative appliances = 5 cases
⊗ = Average level of 22 cases of major orthopaedic surgery in which no foreign material was used
▲ = Patients with fresh fractures of the neck of the femur in whom the fracture was reduced and fixed with a Smith-Petersen nail = 4 cases
Pre-op. Post-operative
INDICATES PERCENT OF PRE-OPERATIVE LEVEL Eosinophilia
Pre-operative Level → 100 %
Relative Eosinopenia
OPERATION
DAY OF
Acrylic Nail
200 and over
180
160
140
120
100
80
60
40
20
0
Pre-op Post 5days 10days 15days 20days 25days 30days 35days over 40days

CHART VIII

Illustrating the prolonged mild eosinopenia in convalescence which occurs in patients with acrylic or metallic fixative appliances. The cause is unknown.

When the preoperative response to the Thorn test was good, the patients withstood major surgical trauma well. Two patients, both over eighty years of age, with excellent ratings in the Thorn tests preoperatively had postoperative courses marked by complete freedom from any disturbance.

Thirty patients were subjected to Thorn tests during convalescence; of these nineteen showed normal responses of 50 per cent. or more. The consecutive eosinophil counts of one patient who showed a negative response to the Thorn test postoperatively are shown in Chart VII. The patient was a girl of fourteen years who was suffering from residual effects of poliomyelitis, with deformity of the right foot. A subtalar and mid-tarsal arthrodesis was performed. She showed a normal drop of eosinophils for two days following operation and then showed marked eosinophilia. This interested us and she was given a Thorn test, in which she showed inadequate response. She was then given fifty milligrams of cortisone; this was followed by a marked drop of eosinophils. This seemed to prove poor adrenocortical response. Nevertheless she made progress without complication and, when again tested on the sixteenth postoperative day, showed a better response, and on the twenty-seventh postoperative day, a normal response. Of ten patients who underwent consecutive Thorn tests, nine ultimately showed good responses, although at one time or another six showed poor responses.

From our observations, we believe it is impossible at this time to draw conclusions about the value of the Thorn test. In our hands a poor response did not preclude a good postoperative course. It is possible that a standard dose of ACTH does not stimulate the same adrenocortical response in all patients. Perhaps the dose should be based on body weight and some patients may require more of the hormone than others to produce the same result. When the response to ACTH is a drop of the eosinophil level of more than 50 per cent. we feel we have definite evidence of good adrenocortical reserve.

Eosinophil Response in Patients with Acrylic Hip Prostheses or Metallic Fixative Appliances

In patients in whom acrylic hip prostheses or large metallic appliances for internal fixation of the bones were employed, it was noted that there generally occurred a significant depression of the postoperative eosinophil levels in comparison with the preoperative levels. Although this depression was not profound, it appeared to be significant, as it was present in nine out of eleven cases in this group, and lasted as long as six to seven weeks. Furthermore, in four patients in whom the metallic appliances were removed the eosinophil levels rose. It should be remembered, however, that the appliances were generally removed because of pain.

The results of our studies in these cases are shown in Chart VIII. It is to be noted that an effort has been made here to reduce all of the cases to a common denominator on a percentage basis. The eosinophil levels on admission were taken arbitrarily as 100 per cent. and the subsequent counts at stated intervals of five days were expressed in terms of percentage of these admission levels. Therefore, levels below 100 per cent. represent relative eosinopenia and those above represent eosinophilia. In order to obtain a mean for comparison, we have taken, as a control, a group of twenty-two patients who were subjected to operations of equal severity, such as hip fusions or spine fusions, in whom no foreign materials were employed and subjected them to the same mathematical procedure.

We have also included in this study a group of patients with fresh fractures of the neck of the femur in whom the fracture was reduced and fixed by the insertion of a Smith-Petersen nail.

The results may be analyzed as follows:

1. *The Control Group* (twenty-two patients): The counts on these patients conformed to the usual pattern previously described. After operation there occurred the usual short period of eosinopenia followed by a rebound to eosinophilia. The levels at five days were nearly 200 per cent. or more compared with the admission level of 100 per cent. Thereafter there was a gradual tapering off of the levels so that they reached normal after forty days.

2. *Patients with Acrylic Hip Prostheses* (six cases): In this group, following the period of postoperative eosinopenia and the rebound, the counts quickly became depressed below the admission level even as long as thirty-five days. Most of these patients did well from a clinical standpoint and there was only one complication in the group. Note that one patient did not conform to this pattern.

3. *Patients in Whom Large Metallic Appliances Were Employed* (five cases): These patients had chiefly complicated fractures for which large metallic appliances were used, such as Küntscher nails or large trochanteric plates. It can be noted from the graph that the eosinophil levels in these patients conformed closely to the pattern seen in the patients with acrylic hip prostheses. They remained depressed below the admission level for approximately five weeks.

4. *Patients with Fresh Fractures of the Neck of the Femur Treated by Reduction and Internal Fixation* (four cases): While the number of patients in this group is too small to be conclusive, the pattern of the eosinophil levels is uniform and therefore suggestive. Upon admission these patients showed eosinopenia as would be expected from the stress of their injuries. Following reduction and internal fixation, there occurred a rapid rebound and persistent eosinophilia at a level of 200 per cent. or more compared with the admission level of 100 per cent. and lasting as long as four weeks. This indicates complete relief of the stress from injury.

All of these observations are based on small groups of cases and are presented only because the findings are suggestive. We have no explanation of these findings and more patients must be studied and for longer periods before they can be considered conclusive.

SUMMARY

We have presented the results of a study of eosinophil levels in 177 patients. Of these, fifty-two were healthy persons used as controls and 125 were patients who were suffering from various disabilities or injuries of the skeletal system and who underwent different surgical procedures. We have described the important metabolic effects taking place in the body, which depend chiefly upon the response of the adrenal gland to the stimulus of injury, and have pointed out the significant findings. We have employed the eosinophil count only as an indicator of these activities.

Finally, it should be pointed out that the metabolic processes we are trying to observe are multiple and complicated. The study of eosinophil levels, which is the method we have employed, may be likened to the opening of one small window through which may be obtained only an imperfect glimpse of the many activities going on within. Many other avenues of approach must be explored before we can penetrate to a point where we can obtain a clearer understanding of these complex mechanisms. We believe that a greater knowledge of them is important to orthopaedic surgeons and will promote the welfare of their patients.

CONCLUSIONS

1. Our studies confirm previous observations that following operation there normally occurs a profound drop in the eosinophil level which is generally followed by a rise to normal or above normal within three or four days. During the period of eosinopenia the patient is ill, and improvement parallels the rising eosinophil counts.

2. Persistent eosinopenia beyond the usual stress period is suggestive of developing complications, either of wound healing or of a general nature.

3. Infections, whether due to pyogenic or tuberculous organisms, cause stress and resultant eosinopenia. As infection is overcome, the counts rise toward eosinophilia. A rising eosinophil count generally parallels a falling sedimentation rate.

4. Eosinophilia when the clinical course of the patient is unsatisfactory is indicative of adrenal insufficiency and should be checked by the Thorn test. A negative result confirms this diagnosis and calls for a trial of cortisone in therapeutic doses.

5. Patients with fresh fractures uniformly showed eosinopenia or evidence of stress. When the fractures had been reduced and fixed there was a rapid rebound to eosinophilia.

6. Immobilization in plaster encasements did not produce evidence of stress. When plaster jackets were employed for correction of deformity, as in scoliosis, the patients showed eosinopenia.

7. Patients with painful conditions, such as acute low-back pain, exhibited signs of stress.

8. Decrease in the eosinophil count did not occur during anaesthesia.

9. Patients in whom acrylic prostheses or large metallic appliances were employed showed persistent eosinopenia lasting as long as five or six weeks.

10. Patients with deformities of congenital origin or with deformities due to poliomyelitis who were admitted for elective surgery showed normal eosinophil levels. Patients with cerebral palsy or neoplasms of the bones or joints showed eosinopenia upon hospital admission.

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PARTIAL RECONSTRUCTION OF THUMB IN A ONE-STAGE OPERATION

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The purpose of this presentation is to call attention to a procedure for reconstruction of the thumb which is very useful in selected cases involving partial loss of this digit. By partial loss is meant absence of the phalanges, the metacarpal remaining intact. The presence of the metacarpal and the thenar musculature makes the reconstruction particularly gratifying because the essential functions of the thumb—opposition, adduction, and abduction—are maintained.

The procedures aiming at reconstruction of the thumb fall into two categories: (1) transposition of another finger or part of a finger to the metacarpal, and (2) prolongation of the existing metacarpal by a skin flap and bone graft.

Transposition of an adjacent index or middle finger with its normal blood and sensory supply presents an excellent substitute for a thumb; this procedure merits the increasing popularity and attention accorded it in recent years. The main drawback of the method is that it calls for the sacrifice of another digit.

The reconstruction of the thumb is seldom performed when the remaining four fingers function normally. As long as the fingers can flex into the palm easily, the grasping function of the hand is maintained. It is only when the fingers have lost some of their length or their range of flexion or both that there is a need to provide an opposable structure with which the fingers can make contact and which enables the patient to grasp and hold small objects. This function is essential in many occupations, even if the patient has a normal second hand and uses the handicapped hand only to perform auxiliary functions, such as manipulating a screw driver with the normal hand and holding the screws with the handicapped one. In many cases the transposition of the finger for reconstruction of the thumb is an obvious procedure, such as when the index finger is partially disabled and does not contribute to the function of the remaining fingers. However, the sacrifice of an index or middle finger may be inadvisable in instances where one or both of these fingers repre-

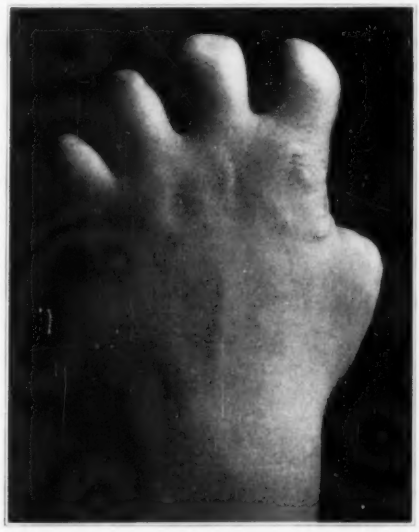

FIG. 1-A

FIG. 1-B

Preoperative appearance of hand. Note the formation of a slight digital cleft by Z-plasty.

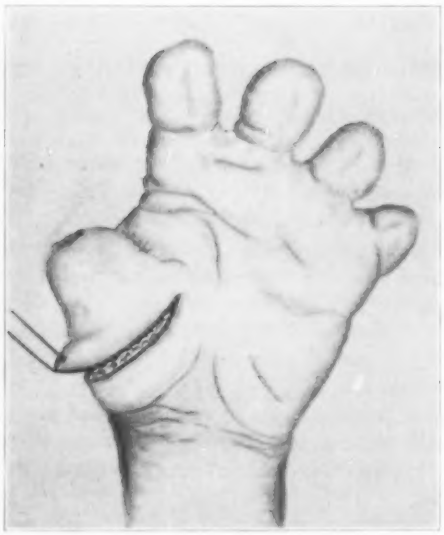

FIG. 2-A

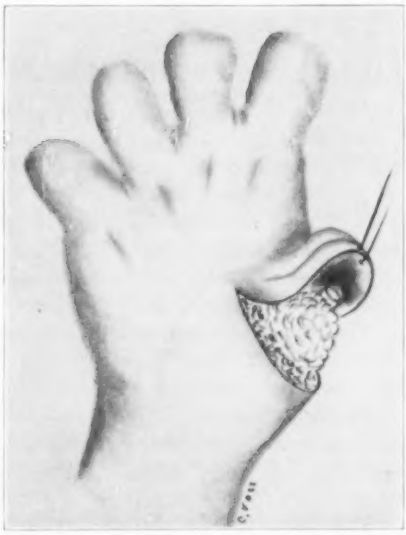

FIG. 2-B

Diagrammatic presentation of procedure.

Fig. 2-A: "Cock-hat" flap outlined on palmar aspects.

Fig. 2-B: Dorsal view showing flap dislodged from tip of metacarpal.

Fig. 2-C: Palmar view demonstrating relationship of cock-hat flap, bone graft, and skin graft at the completion of the procedure.

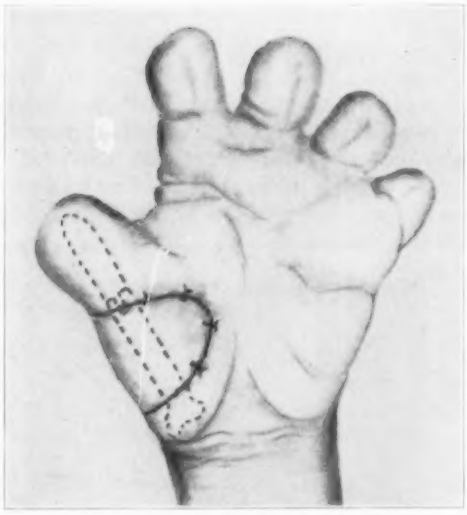

FIG. 2-C

sent the main functional element of the hand. Methods of transposition of digits from the opposite hand or from the foot are too complicated to justify wide application.

The lengthening of the metacarpal used to be accomplished by attachment of an abdominal-skin tube to the stump of the metacarpal and insertion of a bone graft to obtain stability. The main disadvantage of such a procedure is that it requires the use of skin foreign to the hand. Recovery of sensation in such a skin flap is very slow and incomplete, and the sense of touch is permanently absent. This presents a severe handicap for the patient, since reduced sensation in the reconstructed digit not only interferes with the performance of skilled functions, but greatly increases the hazards of injury. Another disadvantage of this procedure is the necessity of multiple operative stages for formation of the tube, its transfer, severance from the donor site, insertion of the bone graft, and defatting of the skin flap.

The procedure described here deals with lengthening of the metacarpal, but it is free from these two disadvantages. Since it utilizes a contiguous flap from the hand which carries a great deal of its own blood and nerve supply, most of the sensation and tactile sensibility are maintained and any temporary loss is quickly re-established. The procedure also permits completion of the entire operation in one surgical step. Hughes and Moore

described a lengthening of the amputated thumb in which a contiguous "cock-hat" flap and bone graft were used. They credited the original idea of a cock-hat flap to Gillies. This method was quickly taken up by d'Aubigné and his associates, who used it in the last two cases out of eight reported reconstructions of the thumb. The French surgeons have shared the enthusiasm of their English colleagues regarding the simplicity of this procedure and the advantage of maintaining nearly normal sensation and tactile sensibility of the reconstructed digit. Since the procedure has thus far found little acceptance in this country, a report on the author's experience with it may be in order.

CASE REPORT

The patient, a sixteen-year-old boy, had suffered an injury to his left hand in an explosion three years previously. The preoperative condition of the hand is shown in Figures 1-A and 1-B. The thumb had been amputated through the metacarpophalangeal joint, and all other fingers at about the level of the proximal phalangeal joint. An attempt had been made elsewhere to deepen the first digital cleft by a Z-plasty, but with little functional improvement. The patient was an apprentice electrician, and an opposable thumb was essential in his work. He refused the suggestion of transposition of the index finger and insisted that the only thing he desired was the lengthening of the stump of the thumb by about two centimeters, which would allow him to oppose it to the index finger.

The presence of scars on both sides of the first digital web resulting from the previous Z-plasty made the formation of a cock-hat flap somewhat precarious. In order that the vitality of the flap could be better assessed, the operation was performed without a tourniquet.

The use of a tourniquet in this procedure is not essential, since the dissection is limited to the subcutaneous plane.

FIG. 3

Fig. 3: Roentgenographic appearance of bone graft four weeks after operation.

Figs. 4-A and 4-B: Appearance eight weeks after operation.

FIG. 4-A

FIG. 4-B

Operative Procedure

A curved incision, five centimeters long, across the radial border of the hand proximal to the tip of the stump, outlined a flap based on the palmar and dorsal surfaces (Fig. 2-A). The dissection proceeded in the fascial plane to avoid injury to the thenar musculature. As the tip of the metacarpal was approached, the dissection extended deeper, so that the entire fibrous pad was included in the flap. The flap was mobilized ulnarward, just enough to dislodge it from the tip of the metacarpal (Fig. 2-B). The area along the digital web on the ulnar side of the stump, on both the palmar and the dorsal aspects, was left undisturbed and served as a fulcrum around which the flap was rotated ulnarward. Since this site represented the pedicle of the flap and was partially traversed by the old scars, great care was exercised to limit the dissection in this location, in order not to interfere further with the source of blood supply to the flap.

An iliac-bone graft five centimeters long was obtained and the cortical elements were removed. It was shaped to form a bevel one centimeter long at the proximal end and was rounded at the distal end. The stump of the metacarpal was then decapped and the bevel of the graft was wedged into the marrow of the bone. A firm union was established without additional fixation. The bone graft extended into the pocket of the flap which was drawn over it. The proximal border of the flap was then basted down along the distal attachment of the muscles to the metacarpal in such a way that it covered the bony juncture. The crescent-shaped raw area over the thenar musculature from which the flap was removed was covered with a split-thickness graft (Fig. 2-C). A pressure dressing was tied over the graft and a large dressing was applied and reinforced with plaster-of-Paris. There was some redundancy of skin around the base of the reconstructed thumb and the flap did not drape itself smoothly around the bone graft.

Postoperative Course

During the postoperative period there was some superficial vascular embarrassment along the radial surface of the flap, which manifested itself by discoloration and desquamation. There was no skin loss. The redundant skin leveled off appreciably during the healing phase, although some wrinkling persisted on the radial aspect of the new thumb.

The rotation of the flap brought the scar and the fibrous pad from the tip of the stump to the ulnar side of the reconstructed thumb. This area was adjacent to the base of the flap and its sensation was disturbed least. From the very beginning the patient claimed that he had normal sensation along this side. However, for about two months there was considerable impairment of sensation along the radial border of the flap. Since roentgenographic examination (Fig. 3) showed firm union in four weeks, the patient was allowed to move his finger and to use his hand. This lengthening of the thumb amounted to almost four centimeters and the patient was able to oppose the new thumb to each of the three fingers on the radial side (Figs. 4-A and 4-B).

In contrast to the procedure used by Hughes and Moore, the cock-hat flap was not slid distally together with the digital web, but was rotated distally and ulnarward, the depth of the digital cleft being maintained. Thus the obliteration of the cleft noticeable in Hughes and Moore's cases was avoided. This modification was dictated by the impairment of vascularization of the flap, due to scars on both sides of the digital web. However, it seems to have a definite application to other cases.

D'Aubigné and his coworkers satisfied themselves with the lengthening of two centimeters, whereas it has been the author's experience that a lengthening up to four centimeters can be accomplished. This corresponds to the length of the proximal phalanx and gives the patient a workable thumb.

SUMMARY

The procedure for lengthening of the first metacarpal in cases of partial loss of the thumb described here utilizes a contiguous skin flap from the hand, reinforced by an iliac-bone graft. It is completed in one operative stage. Its prerequisite is the presence of intact skin along the radial border of the hand.

It is not suggested that this procedure will replace the reconstruction of the thumb by transposition of a neighboring finger, but, if feasible, it is preferable to a method of repair in which an abdominal-skin tube is used. The use of the local hand flap imparts nearly normal sensation and a tactile sense to the new thumb.

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THE USE OF IPRONIAZID IN THE TREATMENT OF BONE AND JOINT TUBERCULOSIS *

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Iproniazid, after having been used for a year in experimental work [1], is still a restricted drug as far as general sale and distribution are concerned. Like any chemical effective in the treatment of disease, it can and frequently does cause toxic symptoms, some of which may be severe. It is certain that complete knowledge as to benefits arising from its use, as well as toxicities, both immediate and delayed, is not available. If one can imagine morphine or any other potent drug introduced for the first time, with its effects noted for only a year, one can appreciate that the clinical picture obtained would be difficult to interpret. So it is with iproniazid. Much more time must elapse before there is certainty as to effective dosage and a means of avoiding toxicity. Isoniazid as contrasted with the iproniazid has been reported as showing a lesser number of toxic symptoms and a greater range of safe dosage. Our feeling, based on seven cases in which isoniazid was used, is that this may be true as to the minor toxic symptoms, but not as to the major ones (liver damage and psychosis). We feel certain that isoniazid has a much less rapid and specific effect where bone and joint lesions are concerned than the iproniazid. Further planned study of the comparative action of these two drugs, carried on without bias, is essential. Discarding our impressions of the past, we plan, in the immediate future, to run a contrasting series of ten patients treated with the isoniazid. With the experience with iproniazid already gained, a much fairer evaluation of the comparative action of the isoniazid can now be obtained.

Although the iproniazid is restricted from general sale, it may be purchased from the manufacturers by any qualified orthopaedic surgeon who will sign for its experimental use and will make reports as to the effects obtained.

The present experiment reports upon the use of iproniazid on sixty-six patients with tuberculosis of bones and joints. Among these patients there were ninety-eight tuberculous lesions; forty-five of these healed, thirty-seven improved, and sixteen are unimproved. Included are a few tuberculous lesions not involving the osseous system, but exclusive of pulmonary tuberculosis (skin, peritoneum, meninges, *et cetera*). Four of these patients have been under continuous medication with iproniazid since November 1951. No adverse findings have resulted from this prolonged medication when dosage has been held within proper limits. We have noted no cumulative effect.

Of the sixty-six patients, we were able positively to prove tuberculosis in forty-seven. In seven we attempted to prove the presence of the *Mycobacterium tuberculosis* and failed. Twelve were admitted with diagnoses of tuberculosis, confirmed at other hospitals but not confirmed by us, since their lesions were closed and we never obtained tissue.

The ages ranged from six months to eighty years; a third of the group, however, were between the ages of forty and fifty years. Seven patients were six years of age or under; these included three who were six months, fifteen months, and seventeen months of age, respectively. Forty were male and twenty-six were female.

The study began in November 1951 and, for the purposes of this paper, was terminated January 1, 1953. Much of the statistical material included in this paper is basic, and the conclusions reached should be fairly stable. The clinical status of patients under treatment, however, is by no means stable. Many unhealed lesions are rapidly healing.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 29, 1953.

It is probable that in some patients recorded as having healed lesions, the same lesions will become reactivated, fresh lesions will develop, or the disease will continue with complications initiated by the original tuberculous process,—such as mixed infections, deformities, and paralyses. As regards laboratory findings, dosage, development of benefits or toxicity, reaction to anaesthesia or preoperative medication, and complications due to operative procedures, the report is fairly conclusive, and no great change is to be expected. As regards the permanency of recovery of patients, tissue-culture studies, nitrogen balance, calcium and phosphorus balance, bone-ash determination, roentgenographic changes, use in combination with other drugs (such as streptomycin), the influence of vitamin therapy or dietary changes (such as salt reduction and high-protein diet), control of withdrawal of medication, and development of late and still unrecognized toxicities, new findings will occur and new conclusions will have to be drawn.

DEATHS

Five patients have died while under treatment with iproniazid. None died with evidence of iproniazid toxicity. One patient succumbed in four days, overwhelmed by tuberculosis before any influence of the drug could be noted. Another patient, who had been on the drug only five days, died of a ruptured aorta eroded by a dissecting abscess. One patient died after forty-seven days with paraplegia; another patient died in a similar condition in ninety days. The fifth patient died in ninety days with eleven severe tuberculous bone and joint lesions, massive dehydration, and loss of electrolyte balance, despite the fact that several of the lesions had healed and cultures for the tuberculous organism had become negative. It is evident that iproniazid is not a "miracle drug"! As will be shown hereafter, however, it is well worth continued use and investigation.

BENEFITS

Weight Gain

All of the sixty-six patients except nine gained weight; the average gain was 15.3 pounds. The greatest gain in one patient was sixty pounds, and the least gain noted was one pound. No patient lost weight during medication, except as a terminal manifestation.

Temperature

Fifty-four of the patients had satisfactory temperature records while hospitalized. Of these, twenty-eight had normal temperatures on starting medication. In cases in which the temperature was above normal, there was a marked reduction in six patients, a moderate reduction in eight, and a mild effect in twelve. No high temperature failed to fall. In the patients who died, no terminal rise was present. (Since the experiment was closed, on January 1, 1953, one patient has died who did have a terminal temperature rise during the last twelve hours.)

Relief of Pain

There were thirty-four patients with pain at the onset of medication. Only four obtained no relief; in thirteen the relief was marked; in eleven, moderate; and in six, mild.

Sinus Healing

There were thirty-eight patients with sinuses. In sixteen patients all sinuses closed and these have stayed healed. In thirteen the sinuses were closed to a dry crusting state or to intermittent closure and dry crusting. Five patients were markedly improved. In four patients, although the character and amount of drainage were influenced, the sinuses did not heal or show evidence of healing. Among these thirty-eight patients were fifty-six sinuses. Thirty-five of these sinuses healed and stayed healed; twenty-one showed improvement to a state of intermittent healing, dry crusting, or reduced drainage.

In five instances, lesions existed in which we would previously have felt sure that sinuses would develop. These five lesions with the angry appearance of imminent breakdown subsided and healed.

Wound Healing

There were thirty-five patients with open wounds as contrasted to sinuses. In sixteen of these the wounds healed; in eleven the wounds healed to a dry crusting state; in four they were improved; and in four there was but little change. Among these last four, moderation in discharge did occur.

Closed Abscesses

Many patients must have had closed abscesses not recognized by us. There were sixteen patients in whom closed abscesses were discovered; in four of these the abscesses resorbed completely; three were greatly improved; and three were slightly improved. In six there was no definite change in the size of the abscess, but the general condition of the patients improved considerably. Lack of appreciable decrease in size of the abscess may be related to additional fibrosis of abscess walls.

Blood-Tinged Discharge

In thirty-three lesions the nature of change of discharge as regards bloody content was noted. There was a marked bloody tinge in two, a moderate tinge in six, a slight change in seven, and no evidence of blood in eight. No hemorrhages occurred. The change frequently followed manipulation of an abscess cavity with a draining sinus or preceded final closure of such a sinus. The phenomenon seemed to be one presaging healing. In no instance was it associated with adverse change in the patient's condition as a whole.

Bacteriostatic Action as Regards the Mycobacterium Tuberculosis

There were thirty-one patients with proved open lesions who, after beginning iproniazid therapy, had a satisfactory series of repeated cultures upon which to form a basis for report. In twenty-seven of these patients either their incisions healed so that no further cultures could be obtained, or they had negative cultures throughout their treatment period. Three have had a single positive culture with many negative cultures. One patient has had an occasional positive culture interspersed among negative cultures.

This situation is amazing. It has been suggested that the organism changes so that it is not now obtainable by the usual culture methods, that it may be becoming nonpathogenic but is still viable, and that many other things may be occurring. We have the feeling that the few positive cultures obtainable, interspersed with negative cultures, may well indicate intermittent casting off of abscess-wall lining or sinus-pocket detritus not freely permeated with circulating body fluids. Such material, intermittently discharged as healing progresses, would naturally contain viable organisms never in contact with the iproniazid concentration present in the blood stream. The bacilli would be like the citizens of Switzerland during the last Great War, entirely surrounded by dramatic conflict, still alive and relatively uninfluenced by the debacle surrounding them. Once leaving the confines of their safe and untouched territory, they would become subject to destruction unless they escaped rapidly through the area of conflict (discharged through the sinus to the outside). If this be so, then prolonged periods of medication will be necessary when bones or joints are involved or large abscess pockets exist.

PREVIOUS ANTIBIOTICS

Of the sixty-six patients, fifty-three had had some amount of streptomycin before iproniazid was begun. In all patients not only streptomycin but all other medication was stopped at the time of beginning the iproniazid therapy.

Four of the patients had had aureomycin of considerable amount, and many of them had had lesser amounts. Terramycin and the other antibiotics had been used in a few cases. One patient had had cortisone administered, and one patient had had dihydrocortone injected into a tuberculous knee joint; adverse results were apparent in both instances. One patient had had streptokinase used in combination with streptomycin; its use was for a very short period, and we saw no direct adverse results. Only the streptomycin and aureomycin have been employed by us.

Streptomycin

Of the fifty-three patients who had had streptomycin, some beneficial effect was still apparent in five. In the other forty-eight, the benefit had ceased or the patient's condition was deteriorating. The average total dose of streptomycin before iproniazid therapy was 256 grams; the greatest amount was 1,020 grams. In thirteen patients the dose had been under 90 grams, and this should be considered ineffectual in bone and joint lesions.

When patients have been improving satisfactorily on streptomycin during the past year, we have not discontinued such therapy and changed these patients to experimentation with iproniazid.

Of the patients who had received streptomycin, three were totally deaf, five had hearing reduction of 50 per cent., and two had definite but slight loss. Three patients had had severe skin reactions under the streptomycin therapy.

Note that this experimentation with iproniazid was carried on as the primary therapy in only thirteen of the sixty-six cases. All of the others represented the residual failures among the many who have been treated with streptomycin by us. We have felt that, until we have determined some fair balance between the advantages of streptomycin and iproniazid and the comparable toxicities of each, administration of iproniazid alone in fresh cases should be restricted. In the main, we have treated the failures of streptomycin therapy with iproniazid. We may yet find ourselves in a position in which we have to treat the failures under iproniazid therapy with streptomycin!

Isoniazid

Seven patients have had varying amounts and length of treatment with isoniazid. While favorable results were noted, the effects seemed much less than with iproniazid. Further studies will be done on a greater number of cases for comparison as to benefits, toxicity, *et cetera*. Our feeling is that the iproniazid is the more effective chemical; this remains to be proved.

LOCAL REACTION OF SINUSES TO IPRONIAZID THERAPY

Discharge

The discharge (Table I) became markedly thinner in fifteen, moderately thinner in eighteen, showed slight change in one, and no effect in one. It became greatly reduced in twelve, moderately reduced in fifteen, slightly reduced in seven, and there was no effect in one. Bloody tinge of considerable extent developed in fifteen, of moderate amount in eighteen, of slight amount in one, and there was no change in one. This summary represents the findings in thirty-five sinuses in which all three types of change were noted.

Granulation Tissue

Of these thirty-five patients with definitely recorded findings, granulations were absent, did not form, or were reduced to below skin-surface level in all except two. In these two, mild excess granulation tissue persisted. Actually, when sinuses healed under iproniazid therapy, the healed opening was routinely depressed below the surrounding surface level. No keloid developed.

TABLE I

CHANGE IN TYPE OF DISCHARGE

	Marked	Moderate	Slight	None
Thin	15	18	1	1
Decreased	12	15	7	1
Bloody	15	18	1	1

Local Oedema

Local oedema was present in seventeen patients before iproniazid therapy was begun. It showed marked reduction in three cases, moderate reduction in nine cases, and slight change in three. In two patients the oedema was unchanged. In all other patients no oedema was present about sinus openings either before or after iproniazid therapy.

Local Heat

Local heat was present before iproniazid therapy in fifteen patients. It was markedly reduced in two, moderately reduced in five, mildly changed in five, and unaffected in three. In all other instances no local heat was present about sinus orifices.

DOSAGE AND WITHDRAWAL

The total amount of iproniazid used in these sixty-six patients was 2,029,159 milligrams. The average amount per patient was 30,744 milligrams. The greatest amount used for a single patient was 123,000 milligrams, and the minimum effective amount used was 3,600 milligrams (in a child). The average maximum dose was 3.6 milligrams per kilogram of body weight, and the minimum 2.7 milligrams per kilogram per day. The highest individual dose was 6 milligrams per kilogram of body weight. This was employed for a four-day period and, although it resulted in rapid healing changes, it was accompanied by severe toxic effects. The lowest dosage was one milligram per kilogram, and this produced no favorable change.

Medication should be begun at an accurate dose of 4 milligrams per kilogram of body weight. The patients must be weighed. As weight is gained, 4 milligrams per kilogram of gain must be added. For severe hypertonicity or clonus the dose should be reduced to 2 milligrams per kilogram of body weight and then gradually increased to between 3 and 4 milligrams per kilogram. Doses under 3 milligrams per kilogram are much less effective.

Close control of the dosage level to maintain close control of the blood-serum level is essential. At any given blood-serum level there is apt to be a 50 per cent. increase in level of concentration in the spinal fluid[2]. Since the serum level necessary to be effective on the *Mycobacterium tuberculosis* is just under the toxic level for tissue cells, and since the level in the spinal fluid is apt to be 50 per cent. above that in the blood serum, very close control of clinical dosage is necessary. We wish to emphasize again that the patient must be weighed and the dosage must be accurate if effect is to be gained and toxicity is to be minimized.

One cannot divide the clinical dosage in half and secure half the effect on the tubercle bacilli within the body. With half the concentration, very little if any effect on the infecting organisms will be exhibited[1]. The concentration in the serum must be kept up to a certain minimum level in order to secure satisfactory results. This emphasizes the fallacy of attempting to give half the amount of streptomycin and half the amount of the iproniazid in combination in order to secure a mutual effect. In such a case practically no effect on the tubercle bacillus may be secured from the iproniazid given. It does seem possible that side effects on the body tissues may occur at lower dosage. Some of these may

eventually prove worth while in specific conditions other than tuberculosis (weight gain, pain relief, wound healing, *et cetera*).

The average number of days' treatment was 140.1. The longest period of treatment was for fourteen months, and the shortest period of treatment in which healing was achieved was twenty-eight days. Rest periods were given in six patients; these were generally allowed because of neurotoxic symptoms. They were for ten days in two cases, and in the others for two days, thirty days, forty-two days, and ninety days. All patients were re-placed on the chemical thereafter at lower dosage and without severe toxic symptoms.

Medication has been permanently stopped in thirty-two patients. Of these twenty-nine are at this time healed and three are improved.

In thirty-three patients who had the chemical permanently stopped, or stopped for rest periods, and where complete data are at hand, medication was slowly withdrawn from fifteen with only one severe neurotoxic finding. In eighteen there was sudden withdrawal, and four had severe neurotoxic findings. Withdrawal over a period of several days is advisable.

TOXIC SYMPTOMS AND FINDINGS

Many neurotoxic symptoms and findings have developed (Table II) during medication with iproniazid. The only one showing evidence of real danger has been the occasional development of a psychosis. All other findings have been temporary and usually not severe. More patients probably had toxic findings than are indicated on the charts. Record of such a finding should denote that the extent of the condition was annoying enough to cause the patient to spontaneously report its presence.

Dizziness

Fourteen of the patients reported dizziness. The average onset was at fourteen days and it lasted sixteen days. Three patients had dizziness throughout the period of medication with this chemical. No patient was severely incapacitated by it.

Tremor

Four patients reported annoying tremor, with an average onset in thirty-six days and an average duration of twenty-three days. Three of the patients complained of tremor throughout the duration of medication.

Babinski

Short, unexplained, and single notation of presence of a Babinski reflex was recorded on two occasions. It was a solitary finding and did not persist. We do not know its implication.

Hypertonic Reflexes

Twenty patients had hypertonic reflexes with an average onset at twenty-seven days' medication, and an average duration of sixty-three days. Ten were hypertonic for the duration of iproniazid therapy. The development of hypertonicity always preceded the onset of clonus. Frequently it had to be accepted as a finding in patients on a satisfactory dosage level. In no instance was it annoying to the patient.

Clonus

Clonus developed in seven patients. Most of these were in the early part of the series and were continued on medication at the same level with persistence of the clonus. Clonus is of a peculiar type and may be present and absent during the same examination. It can generally be made persistent by holding the patient's attention to the part ex-

TABLE II

SYMPTOMS OF TEMPORARY TOXICITY

	No. of Cases		No. of Cases
Hypertonicity	20	Flushing	12
Obstipation	15	Drowsiness	12
Euphoria	15	Hesitancy	10
Dizziness	14	Clonus	7
Dry Mouth	12	Impotence	5
Visual	5	Tinnitus	2
Tremor	4	Increased libido	2
Twitching	3	Paraesthesia	2
Diaphoresis	3	Headache	1
Babinski	2	Nausea	1

amined. It should be avoided by reduction of drug dosage, since most of the other neurotoxic symptoms (and particularly psychosis) are then usually mild or absent. The average onset occurred nineteen days after institution of therapy and it lasted until drug administration was reduced or stopped. In one patient it was mild; in two, moderate; in three, severe; and in one, very severe.

Euphoria

Actually, euphoria of some amount was seen promptly in almost every patient. In fifteen patients it was of considerable extent. Among these patients the average time of onset was ninety days and the duration averaged fifty-two days. It tended gradually to fade out after onset. In only five patients did it persist for the duration of medication. While undoubtedly of neurotoxic origin, it is a very helpful finding. The patient's viewpoint is changed from a depressed attitude to a happy or elated outlook.

Drowsiness

Twelve patients reported considerable drowsiness. The average period of onset was ten days after medication and the average duration was seventeen days. Even on continued medication, almost all patients recovered from this symptom. Temporary drowsiness occasionally recurred on withdrawal of medication. In no instance was drowsiness severe.

Headaches

One patient reported headache, developing at 120 days and lasting for the duration of medication, but ceasing on withdrawal of the drug. No patients reported insomnia while on medication.

Tinnitus

Two patients reported fairly severe tinnitus, developing at thirty days and at ninety days of medication. In one it lasted for ten days and in the other for the duration of medication. One patient had associated nausea.

Psychosis

A definite psychosis developed in six patients. In two it was mild; in one it was moderate; and in three, severe. The average time of onset was at 142 days of medication (forty-five to 300 days). The average duration of the acute psychotic state was thirteen days (one to thirty days). Iproniazid therapy had suddenly been withdrawn from one of these patients and the psychosis developed three days thereafter. All of these patients have

completely recovered.* None of the patients became violent. In most of them clonus had existed for several weeks before psychosis developed. Keeping medication below the level inducing severe hypertonicity or clonus development and slow withdrawal of medication will probably lessen the incidence and severity of this finding. Personal communication[4] indicates that heavy dosage with vitamin B_6 may prove specific for alleviating the psychotic tendency and rapidly terminating it. With the patients recovering, we have hesitated to try this.

Coma

Coma developed in one patient after ninety days of medication and the coma persisted for two days with complete resolution and no permanent effects. This case has previously been reported as a patient in whom severe jaundice developed after the closure of a lumbar sinus. All laboratory tests, medical and surgical consultation indicated obstructive jaundice instead of toxic jaundice. The sinus reopened and the patient recovered consciousness within forty-eight hours. She recovered from the jaundice completely in approximately three weeks. Later the sinus again alternately closed and spotted and then finally completely closed. It has since remained closed without recurrence of symptoms of retroperitoneal pressure or any neurotoxic or hepatotoxic manifestation. Retroperitoneal pressure on the common duct from sinus closure and abscess pressure could have been the immediate cause of the jaundice and of the coma.

Mouth Dryness

This was reported in twelve patients with an average time of onset of eleven days and an average duration of fifteen days. It disappeared on continued medication.

Diaphoresis

Three patients complained of diaphoresis with onset between the tenth and forty-second day of medication. It disappeared within three weeks in all cases with medication still continued.

Visual

Visual accommodation weakness, with the patient unable to rapidly change from near to far vision, occurred in five patients. Average onset was at twenty-one days of medication and average duration was sixteen days. No permanent defects have been disclosed by ophthalmological examinations and all patients are at present recovered.

Hesitancy

This occurred in ten patients and was fairly severe in three, requiring catheterization in two. It was usually first noted after three weeks' treatment and tended to disappear within a week. All patients have recovered from this.

Obstipation

Fifteen patients reported obstipation, occurring after three weeks of medication and lasting for approximately a month. In six it persisted throughout treatment. In none was it severe.

Impotence

Five patients reported impotence, lasting throughout the duration of medication in one. The average onset was at thirty days and the complaint tended to persist for several weeks. Two patients reported increased libido at about the same period of onset, but it was of much shorter duration.

* As of May 1953.

Flushing

Flushing of the face, annoying in amount, occurred in twelve patients with fairly rapid onset after institution of medication. It slowly faded out during the ensuing six to eight weeks.

Twitching

Muscle twitching of annoying extent was reported in three patients, occurring usually in the seventh week. In only two did it persist for any length of time. It subsided in two patients while still under medication, but lasted throughout the duration in one.

Paraesthesia

Two patients reported annoying paraesthesia. In one it began after fourteen days of medication and in the other after 210 days. In the first it continued for six months, but finally disappeared. In the latter it lasted throughout the duration of medication; it disappeared after therapy had been discontinued.

HOSPITALIZATION

Of these sixty-six patients, forty-six received all of their medication while they were hospitalized. Fourteen of the patients were hospitalized until chemical-dosage therapy could be established and balanced against toxic reaction, and then they were continued on medication outside the hospital. Six patients received the chemical as out-patients entirely. This practice we feel to be dangerous at the present time; hospitalization for two to four weeks during the establishment of medication, even in the ambulatory patient, would seem necessary. Since the situation requiring treatment with iproniazid is serious in itself and in its implications, such hospitalization is not unwarranted.

LABORATORY FINDINGS

Urinary analysis in fifty-eight patients, complete blood counts in forty-five patients, total protein and albumin-globulin-ratio estimation in twenty-seven patients, alkaline-phosphatase estimation with calcium and phosphorus studies in thirteen patients, sedimentation-rate estimation in thirty-two patients, prothrombin-time estimation in five patients, 17-ketosteroid evaluation in three patients, and acid-phosphatase evaluation in one patient, all were with normal findings.

Among patients in whom platelet counts were done, the findings were normal in fourteen. Thirteen patients showed a drop in count up to 50 per cent. In two patients there was an increase in count. We believe that there is a definite influence on the blood platelets under iproniazid medication; the implication of this is for the present not known.

Circulating eosinophils showed no change on five occasions, but did show a positive drop on one occasion with the patient under iproniazid therapy. We have been unable to determine the cause for this one instance.

Liver-Function Tests

In fourteen patients, for various reasons routine liver-function tests were not consistently and periodically made. Of the other fifty-two patients, forty-three had completely normal liver-function tests throughout the duration of iproniazid therapy. Nine patients at some time showed evidence of liver damage by laboratory test. Only two patients showed jaundice at any time; in one case it was mild, in the other severe. The two patients with jaundice, as well as those showing evidence of liver damage by tests, either on continued iproniazid therapy at the same or lower dosage, or following discontinuance of such therapy, have been shown by later estimations to have recovered to normal findings. Liver-function tests should be done, but these need not be carried out so frequently as in the past.

ANAESTHESIA

Anaesthetics have been given to twenty-three of this group of patients. In eight instances cyclopropane was used; in eight, nitrous oxide; in seven, sodium pentothal; and in three, ether. These agents have been used in combination. One patient had procaine spinal anaesthesia. No complications or adverse reactions have been noted. No difficulty was experienced either in induction or in maintenance of anaesthesia, and no undue amounts of the agent used were needed.

Preoperative medication used consisted of morphine sulphate, thirteen times; scopolamine, thirteen times; atropine, five times; demerol, five times; and sodium nembutal, twice. These drugs were used in combination at times. No adverse reaction as to amounts necessary or complicating circumstances was noted.

OPERATIVE PROCEDURES

Among these sixty-six patients, twenty-three operative procedures were performed,—seven spine fusions, two hip-joint excisions, one fixation of a trochanteric fracture by a Jewett nail, one large wound débridement, one excision of the acromioclavicular joint, one ablation of a femoral condyle, two amputations, one elbow-joint resection, one reduction of a fracture of the femur, and six incisions and drainages. No complications as to operation were encountered. There was no unusual bleeding, no postoperative hemorrhage, no unusual shock, no operative accident, and no deaths. Wound healing was unusually good.

The average anaesthesia time was sixty-two minutes, with the longest 135 minutes and the shortest fifteen minutes.

Postoperative pain was decreased markedly in eight cases and moderately in four. In six instances there was no change in estimated postoperative pain relief.

It seemed important to specifically record reaction of patients under iproniazid therapy to anaesthesia, pre-anaesthetic agents, and operative intervention, in view of other reports that such anaesthesia or operation might prove dangerous. The fact that twenty-three patients of a group of sixty-six were anaesthetized and were operated upon without complication should refute these reports. It likewise indicates that iproniazid therapy alone and without surgery cannot be expected to secure favorable results, but that surgery when indicated, in combination with medication, is still necessary.

TISSUE CULTURE

In a personal communication [4] it is stated that tissue culture has been carried on in regard to capillary proliferation and stimulation of epithelial tissue and fibroblasts, as a representative mesodermal tissue. Results have been negative. If concentration of iproniazid in the tissue-culture medium is raised above the high level occasionally found in blood serum in patients under treatment (3.5 gammas per milliliter), growth is inhibited. In no case did growth seem stimulated regardless of concentration.

PRESENT STATUS OF PATIENTS

Of the sixty-six patients, twenty-nine are healed, and medication has been discontinued. Five are healed but still on medication, twenty are improved and still on medication, and three are improved and have been taken off medication. Five have died and one will probably die. Two had less than one week of treatment. One patient has remained entirely unimproved.

Two children have recovered as to proved lesions of the knee; the drug has been discontinued; and they are fully ambulatory, with essentially normal knees. It is too early to be sure, but it seems probable that their lesions are healed and with the joints mobile.

Roentgenographic Changes

Generalized osseous decalcification after several weeks of medication still seems to occur. Bone proliferation or hastening of surgical ankyloses has not seemed to be present.

Actually there is no noteworthy trend either as to increasing or decreasing osteogenesis. This contrasts with statements in our previous paper[2]. No new findings related to roentgenograms have been noted.

SUGGESTED FURTHER INVESTIGATION

Since our previous paper[2] some slight advance has been made. Further work on circulating eosinophils is advisable.

A study of bone ash as to calcium and phosphorus loss and a study of nitrogen balance are planned. Perhaps these may give some clue to the apparent roentgenographic changes of decalcification occurring with prolonged iproniazid medication.

Calcium-Phosphorus Balance

In two patients experiments on calcium-phosphorus balance have been run[3]. More extensive and more closely controlled studies are indicated. This can only be considered as a pilot study. It does seem to definitely indicate certain things. For that reason it is included in this report.

The results are qualitative and not quantitative. All of the factors were not controlled in running the experiment, as they would have been in animal experimentation. Calcium values were derived from food tables instead of having a large supply of standard food prepared in advance and the values adhered to. Patients were followed first on a two-week period without iproniazid therapy and then on a two-week period with iproniazid therapy.

There was no great change from the normal, either as to calcium or phosphorus urinary excretion, before therapy was begun. On iproniazid medication, there was change with definite decrease of calcium output for the first nine or ten days. Then, during the last four or five days, there was a definite increase in both calcium and phosphorus urinary excretion. In the first patient, the urinary excretion of calcium was .507 grams per day average during the period before iproniazid therapy; during iproniazid therapy calcium excretion was .316 grams per day until the last four days, when it rose to .420 grams per day. Phosphorus excretion seemed to increase also and to about the same extent as the calcium.

The stool excretion of calcium from one patient rose from 4.2 grams for the total two-week period before iproniazid therapy to 4.62 grams for the total period of iproniazid medication. Stool excretion in the second patient was not reliable.

Despite the apparent increased excretion of calcium in the urine and in one patient in the faeces, there was for the total period a positive calcium balance and a negative phosphorus balance. We feel that the excretion figures are approximately correct, but that the total calcium-balance figures are inexact, because of the failure to secure findings in the stool of one patient and the placing of estimation as to calcium intake on food tables instead of upon actual food measurements.

The laboratory personnel felt very strongly that, since there appeared to be no great change in either calcium or phosphorus excretion in the first ten days of iproniazid administration, but a decided change during the last four days, a more extended period of investigation might well disclose a definite and important change in the calcium and phosphorus excretion and calcium and phosphorus balance.

CONCLUSIONS

1. Iproniazid has a great effect in the control of bone and joint infection by the *Mycobacterium tuberculosis*.

2. For the present we believe iproniazid to be the drug of choice in the treatment of tuberculous bone and joint lesions. It has proved of great value in patients not responding satisfactorily to preceding antibiotic therapy.

3. Patients under medication exhibit multiple evidences of toxicity. All these are

mild or reversible and appear unimportant, except possibly psychosis. Psychoses appear rarely, can probably be avoided by dosage reduction, and also seem reversible.

4. Iproniazid therapy must be combined with good medical care, dietary care, and surgery when indicated.

5. It may be that, by the use of this drug in children, a tuberculous weight-bearing joint may be spared arthrodesis. Never before have we felt we could make such a statement.

6. In tuberculous patients with severe or multiple involvement, a percentage of mortality and failure must be expected.

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4. Sevringhaus, E. L. (Director of Clinical Research, Hoffmann-LaRoche, Inc., Nutley, New Jersey): Personal communication.

DISCUSSION

Dr. Edward T. Evans, Minneapolis, Minnesota: I wish to stress a few points:

1. Tuberculosis is a generalized systemic disease the care of which requires the teamwork of all concerned. The surgeon is only an adjunct to that care and contributes within the limits of his knowledge and skill. He is a member of a coordinated team.

2. Tuberculosis is never healed except by total ablation. It is only clinically arrested.

3. The review[a] by Dr. Ghormley, Dr. Bickel, and myself of the Veterans Administration cases and the Public Health material has shown that twenty-eight to thirty months is the average minimum observation period required to declare a tuberculous bone lesion irreversible.

4. No present antibiotic, despite its early enthusiastic acceptance, has proved a panacea nor alone replaced other coordinated therapy by the team.

5. Dr. Bosworth's cases are from that group which have proved resistant to other forms of therapy, and I know that he will extend his studies with this toxic drug only with the greatest caution.

May I plead here that any of us who may use this drug do so under the most exacting research restraints, so that in due time we may merit the Gold Medal Award so rightfully deserved by Dr. Bosworth this year.

a. Evaluation of Streptomycin Therapy in a Controlled Series of Ninety Cases of Skeletal Tuberculosis. A Public Health Service Cooperative Investigation. J. Bone and Joint Surg., **34-A:** 288–298, Apr. 1952.

Dr. Stendahl, Oslo, Norway: I feel it a great honor to be allowed to discuss this paper of Dr. Bosworth's.

I have not had any personal experience with iproniazid drugs, but during the last four or five years in the hospital in Oslo, Norway, I have seen the immense improvement brought about by streptomycin in the prognosis of bone and joint tuberculosis; and I feel that the basic principles are the same whether one or the other drug is used, even if iproniazid seems a lot more potent. During this time, we have learned that the goal for treatment of bone tuberculosis must be the eradication of tuberculous foci and that this is possible to a greater extent and in more patients by the use of streptomycin and para-aminosalicylic acid in addition to surgery. It has been shown by Dr. Ursing and Dr. Crell that, even in a number of cases of Pott's disease, treatment can be used according to this principle. We feel that streptomycin is indicated mainly in addition to surgery and prior to it, in order to make surgery possible. I should think that these considerations would be valid also for iproniazid.

We think that we have been able to save some few joints without surgery. Some patients with proved tuberculosis of the knee joint, in fairly early cases of synovial lesions, have been treated with streptomycin and para-aminosalicylic acid systemically, as well as with streptomycin intra-articularly. Thirteen of these patients have been observed for eighteen to forty-eight months. In three of them, there has been relapse with some exudate and positive cultures; but ten patients are so far completely free of symptoms, except that three of them have slightly restricted flexion.

I understand that iproniazid penetrates synovial membranes very freely, but still I think that the high concentration obtained by local treatment must be very beneficial.

(*Continued on page 625*)

ALTERATIONS OF THE LUMBAR CURVE RELATED TO POSTURE AND SEATING *

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INTRODUCTION

One of the most common complaints of persons with low-back pain is inability to sit in comfort, with difficulty in straightening the back on rising. This is particularly noticeable after long sitting in a lounge chair, an automobile, or a theater seat, all of which are supposed to be comfortable. This common complaint must represent some fundamental defect in our conception of the correct sitting position and in the design of chairs and seats, for only young persons with elastic ligaments and no back pain can tolerate sitting for long in the type of seats commonly designed. Older persons, who use chairs more often, do not have this elasticity and often sit in discomfort.

This article will present an analysis of the subject of seating in relation to back symptoms. This work is based on a careful clinical study of over 3,000 persons with low-back complaints, 1,504 of whom have been operated upon for herniation of a lower lumbar intervertebral disc [4,5,6,7,8,9,10], as well as on a special study of the alteration of the lumbar curve in various sitting and standing positions.

Chair and seat manufacturers have done little scientific study of the anatomical, physiological, and pathological factors involved in low-back complaints related to seating. Too often home-furniture manufacturers have followed standard or classic models of chairs, designed many years or centuries ago and based largely on the trial-and-error method, or they have thought more of the luxurious appearance and sales appeal of the chair than of the user's requirements for comfort. The designers of supposedly comfortable lounge chairs have created monstrosities of overstuffed half-beds which provide neither a comfortable sitting nor a comfortable reclining position, permit no change of position, and are impossible to rise from without assistance. Manufacturers of seats for offices, schools, and transportation facilities have made a greater effort to study the conformation and posture needs of the body in relation to seating; they have based their designs largely on anthropometric measurements [3] and on the ideas of designing engineers, and some progress has been made in this field. The anatomy and physiology of the problem of sitting have been excellently presented in a recent monograph by Akerblom, but there is still a lack of understanding of the pathological causes of most postural low-back pain related to seating. It seems time that recently acquired knowledge of the pathology of lower lumbar intervertebral discs be applied to the seating problem, and more correct fundamental rules be presented for the design of seats for the many persons with low-back complaints; these rules are equally applicable to normal persons.

It now is recognized that the site of most back symptoms arising from postural factors is in the lower lumbar spine, particularly in the fourth and fifth lumbar intervertebral discs which commonly degenerate with age under normal weight-bearing, sitting, and stooping strain. Man's assumption of the erect posture has resulted in a lumbosacral region poorly constructed to support the strain of active physical life. It is a rare person who reaches middle age without experiencing some postural low-back pain when sitting or stooping (Fig. 1). In middle-aged people some loss of elasticity has occurred in intervertebral discs and ligaments, and obliteration of the lumbar curve tends to force the degenerated and somewhat separated central portion of the lower lumbar discs posteriorly

* Read at the Meeting of the Clinical Orthopaedic Society, Omaha, Nebraska, October 6, 1951.

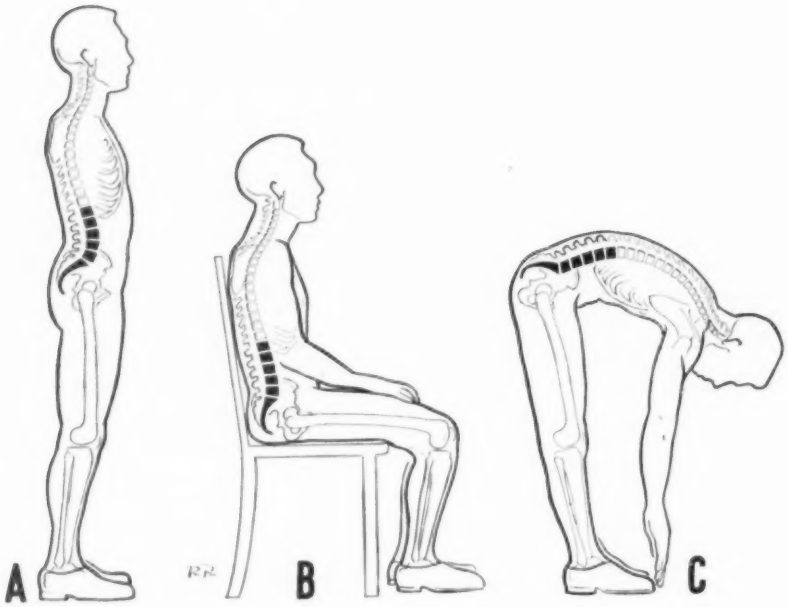

FIG. 1

Tracings from roentgenograms and photographs, made in order to compare the lumbosacral curve in standing, sitting, and stooping. Note the marked flattening of the lumbosacral curve which occurs when the subject is sitting in the ordinary straight chair with trunk and thighs at a right angle.

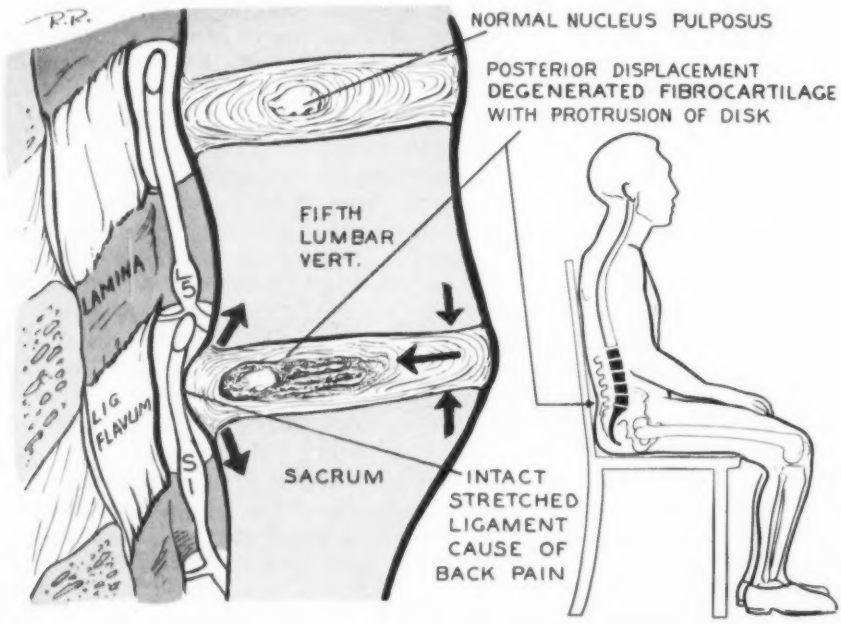

FIG. 2

Drawing to illustrate the anatomy and mechanics of posterior protrusion of a degenerated fifth lumbar intervertebral disc during sitting in a right-angled position.

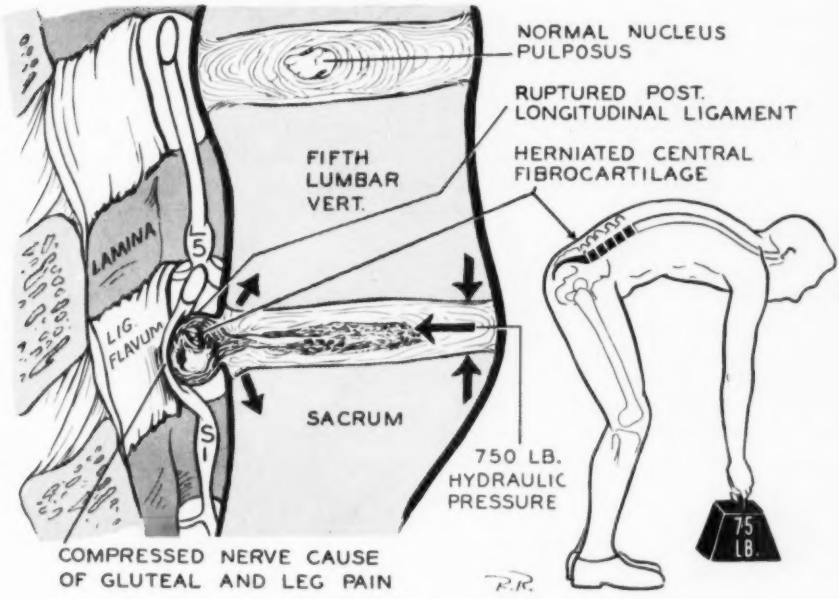

FIG. 3

Fig. 3: Drawing to illustrate the anatomy and mechanics of posterior extrusion of a degenerated central fibrocartilage from the fifth lumbar intervertebral disc, caused by hydraulic wedging pressure within the disc which results from stooping to lift.

Fig. 4: Comparison of the lumbosacral curve of the dog, the newborn infant, and the erect standing adult. Note the dorsal convexity of the lumbar spine of the newborn infant, similar to that in the quadruped animal, compared with the acquired dorsal concavity of the adult lumbar spine.

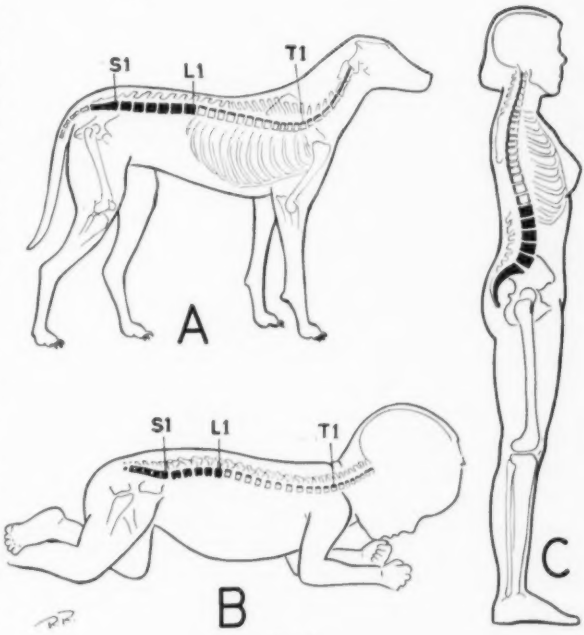

FIG. 4

by hydraulic pressure from anterior wedging. This occurs in variable degree in sitting (Fig. 2), and causes painful stretching of the sensitive posterior longitudinal ligament of the disc, with pain in the mid-line of the low back. In the stooping position (Fig. 3), particularly in lifting, this hydraulic pressure is greatly increased; it is estimated to be ten to fifteen times the amount of the weight lifted [2] and frequently causes rupture of the disc and extrusion or herniation of the loose central fibrocartilage posterolaterally. If this extrusion is large enough, it causes variable pressure on one overlying nerve root within the spinal canal, with resultant radiating pain into one buttock and lower extremity; this pain was formerly called sciatica. The nerve root involved in the back usually can be identified

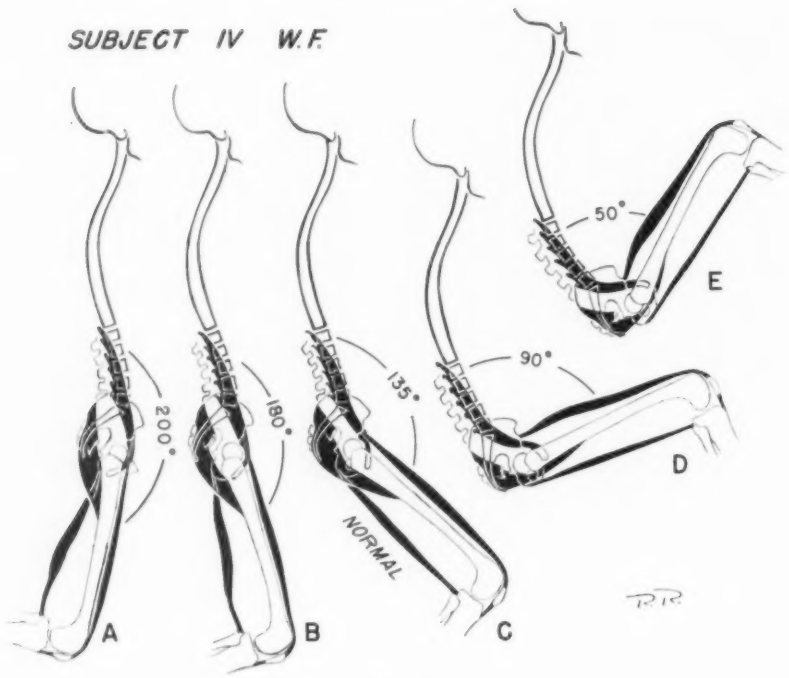

FIG. 5

A series of tracings from roentgenograms of the lumbosacral spine, pelvis, and femur of one individual (Subject IV), in the lateral recumbent position, only the angle between trunk and thighs being varied. A diagrammatic outline of the anterior and posterior thigh muscles is superimposed to show that the limited length of these muscles rotates the pelvis and alters the lumbar curve. Note the normal position of balanced muscle relaxation at 135 degrees, with increase of the lumbar curve as the thighs are brought backward and decrease of this curve as the angle between the thighs and the trunk is reduced.

accurately by the distribution of pain and numb sensation, often with additional diagnostic sensory, motor, and reflex loss in the extremity. Interestingly, when this rupture and extrusion of the disc occurs, the mid-line pain in the low back often disappears; and only lateral "hip" or gluteal pain, together with pain in the lower extremity, is then present, because the ruptured sensitive ligament over the disc is no longer stretched and only nerve-compression pain is present.

Many anatomical and physiological factors are involved in the development of low-back symptoms and pain from postural causes. The curve of the lumbar spine in adult man is developed and established by assumption of the erect position for standing and walking. This dorsal concavity or lumbar lordosis is not present in the newborn infant or in quadruped animals (Fig. 4). This foetal curve in man is reversed during the first few years of life when the child is learning to walk, because of the inability of the pelvis to rotate ninety degrees and to maintain alignment with the vertical trunk. The result is a sacrum which is angulated posteriorly in variable degree in different individuals and a lumbar curve which has become well established in adult life. The fixation of the sacrum in the pelvis is an important factor in placing extra anterior wedging strain on the lower lumbar intervertebral discs when the lumbar curve is flattened by sitting or stooping. This explains why posterior protrusion or extrusion of lumbar intervertebral discs usually occurs in the fourth and fifth lumbar discs and rarely above this level, as freer movement of the upper lumbar spine distributes the force on these discs more evenly. The posterior thigh and gluteal muscles play an important part in flattening of the lumbar curve in

sitting, for they arise from the ischial tuberosity, the posterior aspect of the sacrum and the ilium; and, as the thighs are flexed, they tend to rotate the pelvis by the tension of their limited length (Fig. 5). Likewise, the anterior trunk-thigh muscles accentuate the lumbar curve in the erect standing position. The female pelvis is shaped differently from that of the male and flexion of the thighs on the trunk is less restricted by heavy muscles and ligaments. This permits women to sit at a right angle and to stoop with less flattening of the lumbar curve. Moreover, the heavier weights lifted by large muscular men seem to predispose them to low-back symptoms.

STUDY OF NORMAL SUBJECTS

A special study was undertaken to show what happens to the curve of the lumbar spine in various sitting and standing positions. Four normal young persons were selected for study, two women and two men, with no history or roentgenographic evidence of abnormality, in order to show the normal physiological alteration of the lumbar spine in various positions. Lateral roentgenograms of the lumbosacral spine of these four young persons were made in different positions. Tracings of these were made, the sacrum being superimposed in each tracing. This gave composite drawings for comparison of the alteration in the lumbosacral curve, the line of the dorsal surface of the vertebral bodies being used to establish the line of the lumbar curve of each position (Fig. 6). This line or curve is somewhat different from the line of the posterior spines of the vertebrae, or more accentuated, but it is more representative of the functional alignment of the lumbar vertebrae and intervertebral discs. Drawings from photographs of each body position are shown with the composite drawings. A rather limited number of positions were studied in Subjects I and II in order to gain some definition of the chief factors and findings involved. A more complete series of positions, sixteen in number, were studied in Subject III and these were supplemented by a series of lateral recumbent positions in Subject IV. While it is difficult to compare the lumbar curves of different individuals, the similarity of the alterations which were observed in all four cases and the fairly complete series in Subject III seemed adequate for the interpretations made. A larger series, including a study of pathologically involved lumbar spines, might be more instructive, but did not seem necessary for the purpose of this paper.

Subject I (M. M.) was a young woman of small stature; her height was five feet three inches, her weight was ninety-eight pounds, and she had no recognizable abnormality of the lumbosacral spine. Five positions for lateral roentgenograms of this subject were used (Fig. 6).

It will be noted that complete obliteration of the lumbosacral curve occurs only in the stooping-lifting position, and that in this position the fifth lumbar disc has changed from the narrow posterior wedge of the standing position to a narrow anterior wedge in the stooping position. This explains why such stooping-lifting strain, by the powerful hydraulic pressure directed posteriorly (Fig. 3), commonly causes sudden posterior extrusion of a degenerated loose central fibrocartilage of the fourth or fifth lumbar disc. The nearest approach to the lumbosacral curve of the standing position is on the high, pivoted stool. In this position there is an angle of about 135 degrees between the trunk and thighs and at the knees. This is the position of balanced relaxation for the muscles of the thighs and legs, and it is the position naturally taken when one is lying in bed on one side, or comfortably supine in a hospital bed or a properly fitted lounge chair; it is also the position so many people take in straight chairs by moving forward in the seat. It represents a more normal lumbosacral curve than the standing position with its increased lordosis, caused by the pull of the anterior thigh muscles on the pelvis. However, in this position the lumbosacral curve is not obliterated, as is shown by the straight line drawn from the first lumbar vertebra to the most posterior part of the sacrum (Fig. 6, *B*). Moreover, there is no significant alteration of the shape of the fourth or fifth lumbar discs in this relaxed position

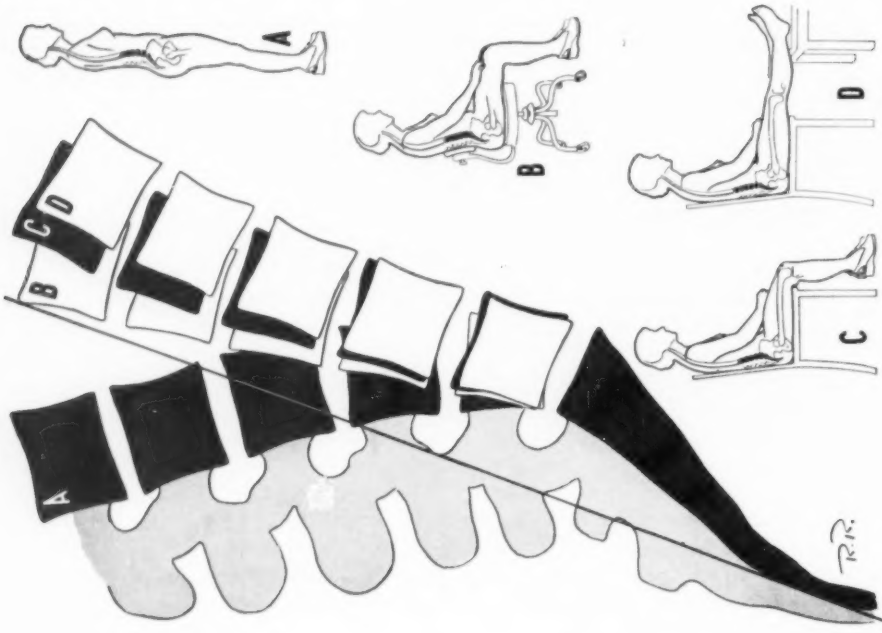

FIG. 7

(See page 595)

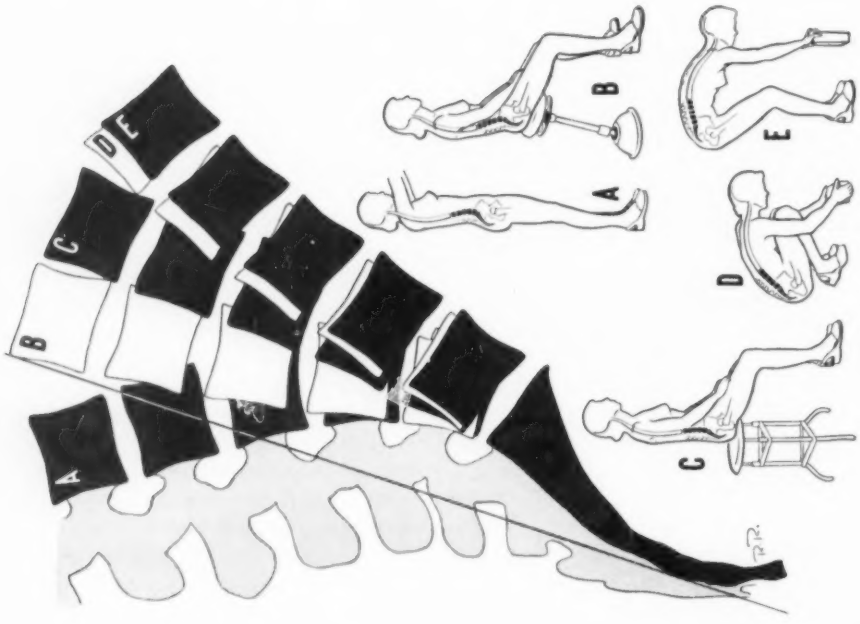

FIG. 6

Fig. 6: Tracings of roentgenograms of the lumbosacral spine of Subject I in five different positions, the sacrum being superimposed in each tracing, illustrated by body photographs. Note position *B* as that of most comfortable balanced muscle relaxation with the trunk-thigh and the knee angles about 135 degrees. This is the physiologically normal adult position, not the standing erect position *A* with its exaggerated lumbar curve.

Fig. 7: Tracings of roentgenograms of the lumbosacral spine of Subject II in four different positions, the sacrum being superimposed in each tracing. The three sitting positions, *B*, *C*, and *D* are similar in that all have the trunk and thighs at right angles, differing only in the type of back support and position at the knees. Note that there is not much difference in the considerable flattening of the lumbar curve in these three sitting positions, indicating that the right-angled trunk-thigh position is the most important factor in flattening of this curve, although there is some protective preservation of this curve with the well placed lumbar back support of position *B*.

and hence no tendency to posterior protrusion of these discs. The slight difference between the lumbosacral curve of the positions shown in Figure 6, *B* and *C*, is due to decrease of the trunk-thigh angle in position *C*, which rotates the lower portion of the pelvis further forward and thus causes some flattening of the curve.

Subject II (R. W.) was a young woman of medium small stature; her height was five feet five inches, her weight 115 pounds, and she had no recognizable abnormality of the lumbosacral spine. Four positions for lateral roentgenograms were used (Fig. 7). It is to be noted that there is surprisingly little difference in the flattening of the lumbosacral curve in the three right-angled sitting positions shown in *B*, *C*, and *D*. The explanation for this is that rotation of the pelvis by the posterior thigh muscles in the right-angled sitting position is a greater determinant in obliteration of the lumbosacral curve than is the absence or presence of low-back support or the position at the knees.

This study emphasizes that the so-called straight or right-angled sitting position causes considerable strain at the lumbosacral junction and explains why this position cannot be tolerated for long by anyone with low-back symptoms caused by intervertebral-disc lesions in the lower lumbar region.

Subject III (J. K.) was a young man of medium stature; his height was five feet nine inches, his weight 155 pounds, and he had no abnormality of the lumbosacral spine except considerable lordosis. A more extensive series of lateral roentgenograms of the lumbosacral spine was made of this subject in order to compare all important positions in one person and to add some which had been suggested by the preceding studies of Subjects I and II. All of the positions used, sixteen in number (Fig. 8), are shown by line tracings of the posterior lumbosacral vertebral-body curve only, with the sacrum superimposed, to avoid confusion of overlapping vertebral-body lines.

In this series it is surprising to note the slight differences in the lumbosacral curve in the first three erect standing positions of *A* (normal), *B* (military), and *C* (relaxed). It is also noteworthy that in the half-stooped position *E*, commonly used to carry a heavy weight on the back, the lumbosacral curve approaches closest to that of the lateral recumbent relaxed position *D*, with trunk-thigh and knee angles about 135 degrees. This relaxed position can more correctly be called the physiological normal for the lumbar curve than any erect standing position, but it is seen to retain considerable curve. The squatting position *H*, with trunk erect, preserves the lumbosacral curve in considerable degree because of hyperflexion of the knees. The maximum flattening of the lumbosacral curve occurs in the extreme stooping position *P*, which places great anterior wedging hydraulic pressure on the lower lumbar intervertebral discs and commonly leads to posterior extrusion of the central fibrocartilage. For better comparison of the six standing positions these are combined in Figure 9, which shows more complete tracings of the lateral roentgenograms. Also in this figure a straight line drawn from the body of the first lumbar vertebra to the most posterior sacral prominence in position *E* shows that the lumbosacral curve is far from flat in this half-stooped position.

Comparison of the lumbosacral curve in the sitting positions in Figure 8, *F*, *G*, *I*, *J*, *K*, *L*, *M*, *N*, and *O*, with the standing erect positions, *A*, *B*, and *C*, shows that in none of the sitting positions does the lumbosacral curve approach very closely to that in

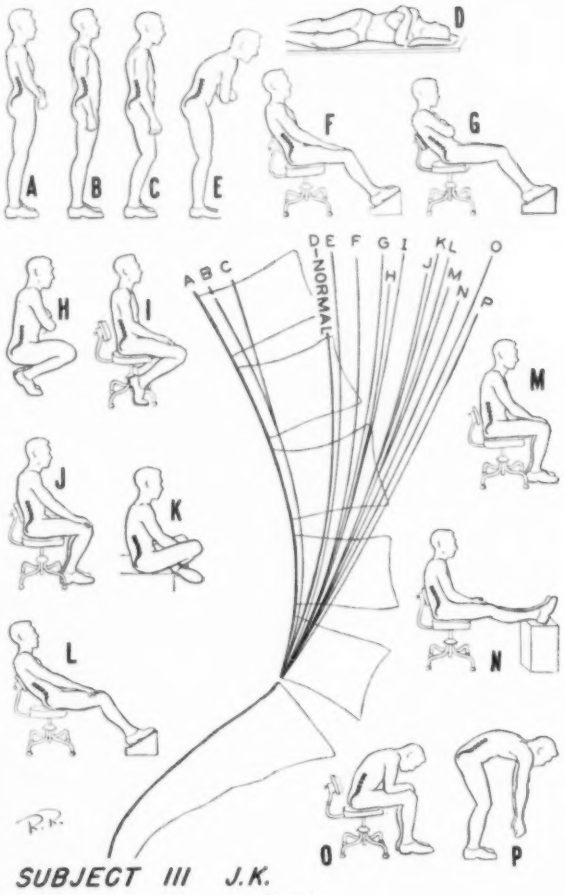

FIG. 8

FIG. 9

(See page 597)

Fig. 8: Tracings from roentgenograms of the lumbosacral spine of Subject III in sixteen different positions. The normal for this individual is established by the lateral recumbent position *D* with the trunk-thigh and knee angles about 135 degrees, as persons lie most comfortably on their sides. The considerable increase of the lumbar curve in the three erect standing positions *A*, *B*, and *C* emphasizes that this places considerable tension on the anterior trunk-thigh muscles and is tiring. The lumbar curve of the somewhat stooped position *E* comes nearest that of the relaxed position *D*, hence is least tiring and safest for heavy load-carrying and lifting. Positions *F* and *G* show comparable sitting positions of 135 degrees, with lumbar support in position *F* and muscle support only in position *G*. Positions *H* and *I* show the influence of hyperflexion of the knees in two right-angled trunk-thigh positions, whereas *J*, with the knees at a right angle, shows more flattening even with lumbar support. The considerably flattened lumbar curve of position *L* is interesting, for it represents the common relaxed lounge-chair position with no lumbar support, conducive to low-back strain, even though the trunk-thigh angle is 135 degrees. The great difference between this curve and that of positions *F* and *G*, with lumbar curve support, is noteworthy. Position *M* is the common unsupported right-angled sitting position, assumed in leaning slightly forward to work at a desk, while positions *O* and *P* represent maximum trunk-thigh angle reduction, all with rather marked flattening of the lumbar curve.

Fig. 9: Tracings of roentgenograms of the lumbosacral spine of Subject III in the five standing positions for better comparison.

the erect standing positions. The nearest approach is in positions *F* and *G*, in which the trunk-thigh and knee angles are maintained at approximately 135 degrees and the lumbar curve is supported either by a low-back rest or by muscle support. Positions *I*, *J*, *K*, *M*, and *N* show variations of the common right-angled trunk-thigh sitting position. The curve of position *I* shows the influence of flexing the legs beneath the chair when one is sitting at a right angle, as this relaxes the posterior thigh muscles and helps to preserve the lumbar curve near that of position *G*. The difference between positions *J* and *M*, with and without back support in the low lumbar area, shows the value of maintaining support at this level when sitting, but such back support with the legs straight, position *N*, cannot overcome the increased pull of the posterior thigh muscles which rotate the pelvis and flatten the back markedly. Position *O* shows the additional flattening of the lumbar curve caused by leaning far forward in the sitting position, near the maximum flattening observed in the stooping position *P*. It should be noted that the common work positions when seated at a desk, *I*, *J*, and *M*, show considerable flattening of the lumbosacral curve and would cause anterior wedging pressure on the lower lumbar intervertebral discs, as well as posterior protrusion of a degenerated disc (Fig. 2). In none of these sitting positions is there complete obliteration of the lumbosacral curve as a whole. Lack of recognition of the posterior prominence of the lower sacrum and the normally recessive fifth lumbar and first sacral spines, and failure to consider the lumbosacral curve as a whole, have led to the incorrect idea that there is no need of special chair-back support at the lumbosacral junction[3] where most pathological low-back conditions and pain develop. The importance of maintaining the trunk-thigh angle at greater than 90 degrees, with a minimum of 105 degrees, has not been realized in the design of most chairs and seats, for the almost 90-degree chair back forces considerable flattening of the lumbar curve and places strain on the lower lumbar discs and ligaments.

Subject IV (W. F.) was a young man of medium slender stature, five feet ten inches tall, and weighing 135 pounds, with no recognizable abnormality of the lumbosacral spine and no history of low-back symptoms. A series of five lateral roentgenograms of the lumbosacral spine were made, with the patient recumbent, to show the influence of thigh extension and flexion on the lumbar curve, the knees being maintained at a constant 90-degree angle and the thorax fixed on the x-ray table. The positions and tracings of these five roentgenograms of the lumbosacral spine are shown in Figure 10.

In this series it is interesting to note the marked alteration of the lumbar curve between positions *C* and *D* which represent the two common seated positions: *C* with the trunk-thigh angle at 135 degrees and *D* with the angle at 90 degrees. The considerable flattening of the lumbar curve in the right-angled position explains why the right-angled sitting position is difficult for persons with back disorders. This series also illustrates well the importance of pull of the anterior and posterior thigh muscles on the pelvis, with consequent rotation backward or forward from the normal, relaxed 135-degree position *C*. This

Fig. 10

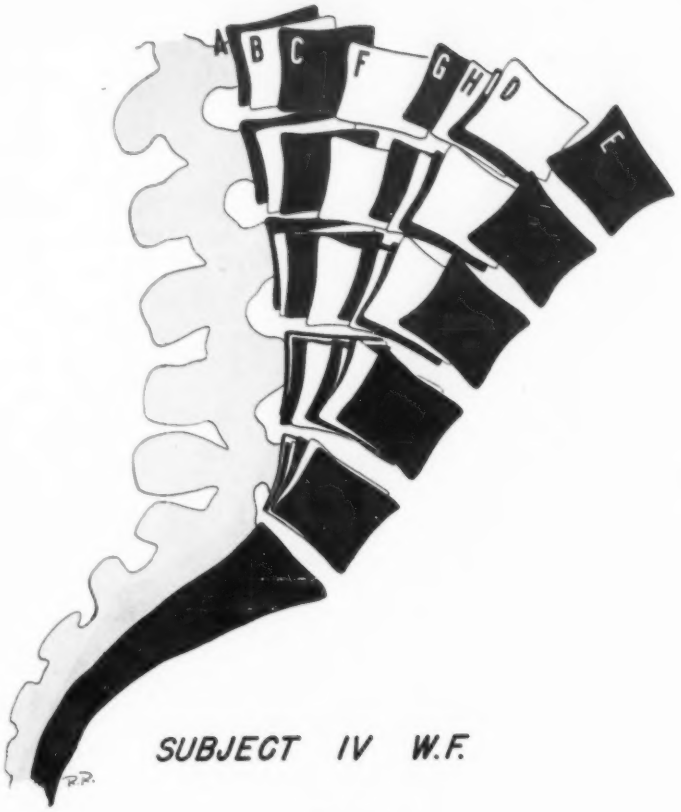

Fig. 11

(See page 599)

Fig. 10: Tracings of roentgenograms of the lumbosacral spine of Subject IV in five lateral recumbent positions, the sacrum being superimposed in each tracing. The only variant in these positions is decrease of the trunk-thigh angle, the thorax and knees being maintained at constant positions. Particularly noteworthy is the great difference in the lumbar curve between position *C* at 135 degrees and position *D* at 90 degrees.

Fig 11: Tracings of roentgenograms of the lumbosacral spine of Subject IV show four decreasingly angled trunk-thigh lateral recumbent positions between 135 degrees and 90 degrees, curve *F* being at 125 degrees, *G* at 115 degrees, *H* at 105 degrees, and *I* at 95 degrees.

Fig. 12: A design outline incorporating the basic requirements for a comfortable and protective seat, based on knowledge of the anatomical, physiological, and pathological causes of low-back discomfort and pain. This basic design is applicable to all seats, regardless of their external form or special use. Eleven distinctive features are numbered on the drawing and are listed below with explanatory notes.

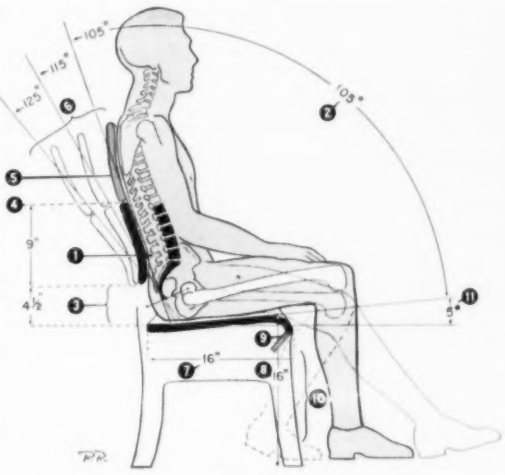

FIG. 12

1. The most distinctive and important feature of this seat design is placement of the primary back support over the lower lumbar spine, where most postural back symptoms are located.

2. The second important feature is the provision of a minimum angle of 105 degrees between the trunk and the thigh to help preserve the lumbar curve.

3. The third feature is provision of an open or recessive space for the posteriorly projecting sacrum and buttocks. This free space permits constant contact with the primary lower lumbar back support.

4. The upper limit of the convex primary lower lumbar back support in the short-backed "straight" chair should be well below the lower angles of the scapulae. This permits unrestricted posterior placement of the shoulders for relaxing change of position in the chair.

5. The shoulder support in high-backed chairs is secondary to the lumbar support, placed at a minimum angle of 105 degrees with the seat.

6. Increase of the angle of the back of the seat is pivoted on a point in line with the hip joint. This permits maintenance of contact with the primary lower lumbar support.

7. The maximum length of the seat is sixteen inches, measured from the most prominent point of the lower lumbar support. This allows free space back of the knees for change of position of the legs.

8. The height of the seat is sixteen inches, to permit comfortable placement of the feet on the floor. If the seat is made higher for desk or table use, it should be made shorter, fourteen inches for the standard thirty-inch-high desk or table, twelve or eight inches for work on a high stool.

9. The front border of the seat is curved downward or upholstered; this aids in molding the thighs over the edge of the seat so that the feet can reach the floor. The joining support beneath the front border should be at a 45-degree angle, so that it will not interfere with placement of the feet beneath the seat.

10. Free space below the seat is provided to allow for placement of the feet beneath the seat in rising and for relaxation in sitting.

11. A tilt or upward inclination of 5 degrees for the seat is provided to aid in maintenance of proper position against the lower lumbar back support.

series of positions is shown diagrammatically in Figure 5, in which the important muscles are outlined on tracings of the lumbosacral spine, pelvis, and thighs of this subject.

Because of the great alteration or flattening of the lumbar curve noted in this subject between the angles of 135 degrees and 90 degrees, a second series of lateral roentgenograms was made in a similar manner. In this series the trunk-thigh angle was reduced in steps of 10 degrees between these angles (Fig. 11). Again the wide difference between the lumbar curves of 135 degrees and 90 degrees may be seen, with progressive intermediate flattening at 125 degrees (*F*), 115 degrees (*G*), and 105 degrees (*H*), and 90 degrees (*I*), somewhat greater between the angles of 125 and 115 degrees than before and after. This indicates that considerable flattening of the lumbar curve occurs at 115 degrees and at 105 degrees, emphasizing that the vulnerable lower lumbar spine needs support in these common sitting positions.

DISCUSSION

The preceding observations on alterations of the lumbar curve related to posture and seating emphasize several important factors in the causation of discomfort and pain

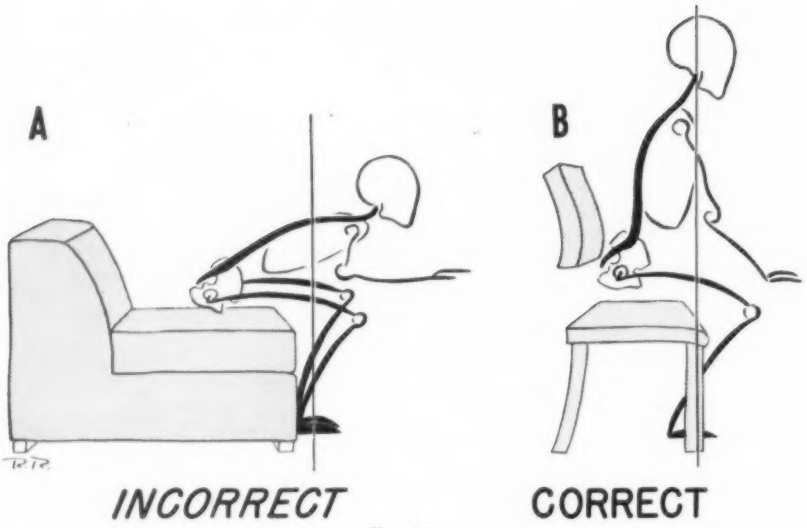

FIG. 13

Diagram to emphasize the difficulty of rising from an incorrectly designed lounge chair *A*, in comparison with a correctly designed chair *B*. The too long seat with closed front necessitates sliding forward and extreme flattening of the lumbar curve in order to rise without assistance. The short seat and open front permit easy placement of feet beneath the center of gravity without the lumbar curve being flattened.

in the lower lumbar or gluteal regions and in the lower extremities, particularly in sitting at a right angle and in flexing the back far forward. While young persons with normally elastic intervertebral discs and ligaments can subject their lumbar spines to considerable stress and strain without discomfort or disability, there is an increasing tendency in those over thirty years of age to experience lower lumbar pain associated with postural strain, and few individuals pass forty years of age without feeling at times some lower lumbar soreness or pain. It is now recognized that a common cause of this postural low-back pain is posterior protrusion of a degenerated fourth or fifth lumbar intervertebral disc, which tends to develop when the lumbar curve is flattened, because of stretching of the sensitive posterior longitudinal ligament over the disc (Figs. 1 and 2). Typically such a person finds it difficult to straighten the back after sitting for long in an ordinary chair, because of the slowness with which the protruding disc resumes its normal shape. When extrusion or true herniation of the degenerated loose central fibrocartilage occurs with pressure on a nerve root (Fig. 3), the lumbar curve becomes set or fixed in a somewhat flattened position, because the herniated tissue cannot return to the center of the disc and remains partly wedged in the posterior portion of the disc. Further flexion or flattening of the lumbar spine, as in sitting or stooping, stretches the sensitized overlying nerve root and increases nerve-root irritation and gluteal and lower-extremity pain. Moreover, standing erect or bending backwards often causes increased nerve-root pain when the mass of herniated tissue is large and leaves little space for the overlying nerve root. Thus it is seen that, during sitting, support of the lower lumbar spine over the fourth and fifth lumbar discs is very important for persons with any degeneration or tendency to posterior protrusion of these intervertebral discs. When extrusion or true herniation has occurred, the patient has to maintain a somewhat fixed position of forward flexion, thus attempting to relieve the pressure on the nerve root as much as possible. Forcing this patient into any other position by manipulation, traction, or brace increases his pain and is liable to further the extrusion and to cause complete loss of function of the nerve root.

As this study of alteration of the lumbar curve in normal subjects progressed, it became increasingly evident that the optimum or physiologically normal position of the

adult spine is with the trunk-thigh angle and the knee angle at approximately 135 degrees, and that in this position there is considerable curve in the lumbar spine. This is the position of balanced muscle relaxation, with the intervertebral discs stabilized in their normal adult shape. Alteration of this normal adult lumbar curve, either forward in sitting and stooping, or backward in standing erect, places greater wedging strain on the lower lumbar discs than on those above, because of the tensing of the long thigh muscles of the opposite side and fixation or rotation of the pelvis (Fig. 5). Consequently it is important to recognize that sitting positions which tend to flatten or obliterate the lumbar curve by decreasing the angle between the thighs and trunk soon become uncomfortable and cannot be tolerated for long by persons with degenerated intervertebral discs in the lower lumbar region. With this basic knowledge of alterations of the lumbosacral curve in standing and sitting positions and recognition of the common cause of postural low-back pain, it is possible to establish correct rules for the design of chairs, applicable to all seats regardless of their purpose, size, or cost. Such a design outline is shown in Figure 12, with the several requirements numbered in order of their importance.

The most important requirement of a correct seat for protection of the vulnerable lower lumbar intervertebral discs is placement of the primary back support over the lower lumbar region (Fig. 12, *1*). Free space or a sharply recessive curve is needed below the lumbosacral juncture (Fig. 12, *3*) to accommodate the posteriorly projecting sacrum and buttocks. The surface of the lower lumbar support should be convex, in conformity with the normal physiological lumbar curve. In small, straight chairs it is better to have the back support end at the thoracolumbar juncture below the lower angles of the scapulae (Fig. 12, *4*), as this permits occasional relaxing restoration of the normal lumbar curve by allowing the person to lean backward without shoulder blocking. Permissive change of position in sitting was considered by Akerblom the most important requirement of a comfortable seat.

Shoulder support (Fig. 12, *5*) has been overemphasized in the design of seats; it is necessary only in semireclining chairs and should always be made secondary to the primary support of the lower lumbar curve. In the semireclining positions the abdominal weight tends to flatten the lumbar curve, so that there is additional need for lumbar support, although increase of the trunk-thigh angle and tension of the anterior muscles help to preserve the lumbar curve in this position. This change of position in adjustable seats should be pivoted on the axis of the hip joint.

The second important requirement for a correct seat is allowance of a minimum trunk-thigh angle of 105 degrees in high-backed chairs (Fig. 12, *2*), in order to prevent too much uncomfortable flattening of the physiologically normal lumbosacral curve in the adult. It is impossible to sit in the common straight chair with a 90-degree or 95-degree angle between the back and the seat without considerable flattening of the lumbosacral curve and painful posterior protrusion of degenerated lower lumbar intervertebral discs. It is a common observation that people who sit in this type of almost right-angled chair tend to slide forward in the seat for more comfort. This is because sliding forward increases the trunk-thigh angle, restores the lumbar curve, and reduces posterior protrusion strain on the lower lumbar intervertebral discs.

Correct design of the seat of the chair is as important as that of the back of the chair and is subject to as many misconceptions of its form and function. The most important requirement is that it be short, never over sixteen inches in length (Fig. 12, *7*), the length being reduced as the seat is made higher. People sit most naturally and comfortably on their buttocks, not on their thighs. The ischial tuberosities of the pelvis furnish the bone support of the trunk weight in sitting. Molding or cushioning the seat helps to distribute the weight more widely. It is not comfortable or useful to extend the seat beyond the mid-thigh region beneath the tendons back of the knees. At least four inches of free space are necessary there to permit some molding of the soft portion of the thighs when the knees are partly extended or flexed, for relaxation and change of position, and for flexion of the

knees in rising. The front space beneath the seat should always be left open or receding at an angle of not less than 45 degrees (Fig. 12, *9*), in order to permit placement of the feet beneath the seat for relaxation and as an aid in rising. It is impossible to get out of a seat which is too long and has a closed or wide vertical front border, except by excessive back flexion and sliding forward to place the center of gravity over the feet in front of the chair (Fig. 13, *A*). The much greater ease of rising from a proper short open-front seat is shown in Figure 13, *B*. Some tilting of the seat is desirable, about 5 degrees above the horizontal in front (Fig. 12, *11*), for ease in maintaining position and for contact with the back of the chair, but this inclination should not be so much nor the seat so long and high that the average short person cannot rest the feet comfortably on the floor with the knees partly extended or flexed.

The height of the seat from the floor may vary according to purpose, the seat necessarily becoming shorter as the distance from the floor is increased, so that the thighs can be directed more downward and the feet can reach the floor. If the seat is of the maximum sixteen-inch length, the height should not be more than sixteen inches. This permits the average short person to reach the floor with his feet and to be able to extend or flex the knees moderately for needed change of position. It is easier for the long-legged person to adjust to a low seat than for the short person to adjust to a high seat. Seats for work or eating over the standard thirty-inch-high desk or table need to be eighteen inches high but not over fourteen inches in depth, to permit the feet to reach the floor comfortably. The reason that sitting on a high stool with a short seat is more comfortable and protective for work over high work tables is that the increased angle between the thighs and the trunk helps to preserve the normal lumbosacral curve. Flexion of the knees beneath the chair, commonly noted in desk workers, likewise helps to preserve the lumbar curve in sitting, by relaxing the posterior trunk-thigh muscles.

Another important requirement is that a sixteen-inch distance be kept from the eyes to the top of a desk or work-table surface, as reading glasses are regularly adjusted for this focal length. While young persons can read at a much closer range than this, it is tiring for their eyes, and older persons with fixed eye lenses seriously need the sixteen-inch reading distance to which their glasses are adjusted. The standard height of desks and tables is thirty inches, some desks being adjustable to twenty-eight inches; card tables are regularly this latter height. The average person sitting in the ordinary straight chair with a seat height of eighteen inches finds that his eyes are too close to the thirty-inch-high desk or table top for comfortable reading and usually resorts to leaning backward somewhat, both to increase his reading distance and to enlarge the angle between trunk and thighs for more comfort when sitting. For work directly over a desk it is better to maintain the desk height of thirty inches, but to elevate the seat to twenty inches and reduce its length to fourteen inches, which permits maintenance of a larger trunk-thigh angle without uncomfortable pressure on the seat edge beneath the mid-thigh region. Desk workers now are usually supplied with a "posture" chair which has an adjustable seat height and fourteen inches of seat length; this should overcome the difficulty of maintaining the proper reading distance of sixteen inches from their work and a desirable trunk-thigh angle of 105 degrees or more. However, most desks are made with such a deep center drawer that it is impossible to sit high enough to maintain proper reading distance, because of contact of the thighs against the drawer. This drawer never should be over two inches in depth; it is better omitted entirely, as it cannot be opened when the worker is seated at the desk. School desks are commonly made with a deep center receptacle, which seriously handicaps the shorter child in maintaining the correct reading distance of sixteen inches.

Molding or cushioning of the seat is desirable for better distribution of weight over the entire buttocks; this is particularly needed for thin persons in whom pressure pain tends to develop over the ischial tuberosities. The front edge of the seat should be turned down or soft-cushioned, in order to permit change of position of the legs without uncomfortable

ridge pressure beneath the thighs. The covering of upholstered chairs should be porous and rough to provide ventilation and fixation. The present tendency to use impervious smooth plastic covering, because of wearing and cleaning advantages, causes uncomfortable moist heat and wrinkling of clothing. The width of the seat can be varied to fit individual needs. The arm rest should provide support beneath the soft muscle part of the forearm, not beneath the elbows, as the latter causes uncomfortable bone and ulnar-nerve pressure, sometimes leading to paralysis of this nerve. Consequently there should be an open or lower space directly beneath the elbow.

The form and measurements of a functionally correct chair should be based on complete knowledge of the anatomical, physiological, and pathological factors involved in low-back pain related to seating, not on anthropometric measurements or on trial-and-error methods of testing with normal persons. A subsequent article will deal with this subject in a more specific manner, with discussion of the faults of types of seats in common use and presentation of correct seat designs.

CONCLUSIONS

The most common cause of low-back pain related to seating is posterior protrusion or extrusion of lower lumbar intervertebral discs.

The normal curve of the lumbar spine in adult man is determined by maintenance of the trunk-thigh and the knee angles at approximately 135 degrees.

Alteration of this normal lumbar curve, either an increase in standing erect or a decrease in sitting or stooping, is caused largely by the limited length and consequent pull of the trunk-thigh muscles of the opposite side.

The most important postural factor in the causation of low-back pain in sitting is decrease of the trunk-thigh angle and consequent flattening of the lumbar curve.

The next most important cause of low-back pain in sitting is lack of primary back support over the vulnerable lower lumbar intervertebral discs.

Added factors of comfort in seating are the shortness of the seat, a rounded narrow front border, an open space beneath for better positioning of the legs, and permissive change of position in the seat.

The design of all seats, regardless of model or size, should be based on this knowledge.

NOTE: The author wishes to express his appreciation to the Department of Radiology and Physical Medicine of the University of Nebraska College of Medicine, Omaha, for the roentgenograms used in this study, and to the medical students who volunteered as subjects for the roentgenograms.

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THE USE OF HYALURONIDASE IN ORTHOPAEDIC SURGERY *

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Hematoma, hemarthrosis, and oedema are conditions faced daily by all orthopaedic surgeons. These collections of extracellular fluid present complicating factors in many of the acute and chronic cases seen in orthopaedic and traumatic surgery. Definitive treatment of the primary pathological change is often delayed while the surgeon waits for nature to dispose of hematoma and oedema rather than risk the dangers incident to the presence of such conditions. A means is now available to accelerate the dispersion of these fluids and thus allow a prompt approach to the problem at hand. The enzyme hyaluronidase has been demonstrated experimentally to accomplish this. Clinically, we have been able to duplicate this finding and the following is a report of over two years' experience with its use at the New York Orthopaedic Hospital.

PHYSIOLOGY

In 1928, Duran-Reynals first reported a specific spreading factor in certain organic tissue. Meyer has since isolated one of these factors, hyaluronidase, from an extract of bull testis. Further investigation by Seifter at the Wyeth Institute has resulted in rather exact knowledge of its physiological and pharmaceutical action.

Hyaluronidase acts directly on the ground substance of certain body tissues by the depolymerization of the mucopolysaccharide, hyaluronic acid. This acid forms the main constituent of normal connective tissue and joint fluid. With the breakdown of these natural barriers a freer flow of intercellular fluid is obtained. This is reflected clinically in rapid dispersion of extracellular fluid collections.

Hyaluronidase itself has no propulsive ability; but Britton and Habif have shown by laboratory experiments that the addition of a mechanical pressure exerted on the fluid collections enhances the action of hyaluronidase by providing a motivating force which will act upon the fluid. Clinically this is supplied externally by an elastic bandage, or internally by increasing the fluid pressure locally at the time of hyaluronidase injection by the addition of fluid.

CLINICAL APPLICATIONS

Sprains

The typical sprained ankle demonstrates clearly the advantage of hyaluronidase therapy. The area of maximum swelling and its periphery are injected with 1,000 TR units † of the enzyme in five cubic centimeters of one per cent. procaine; an elastic bandage is snugly applied; and the patient is allowed to walk with full weight-bearing, for pain is absent. When the patient is examined one or two hours later, the swelling and hematoma are found to be greatly reduced. The elastic bandage is reapplied, and the patient is followed in the usual manner. By allowing the patient immediate painless weight-bearing, the disability time is greatly reduced. The recovery period is further shortened by preventing the brawny thickened induration so often seen following severe sprain. The tissues and local circulatory conditions are rapidly restored to a normal state, and the reparative process at the site of the ligamentous tear is thereby hastened.

* Presented at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 29, 1953.

† A TR (turbidity reduction) unit is that quantity of the enzyme which will reduce turbidity in thirty minutes from that which corresponds to 200 gammas of the sodium hyaluronate to 100 gammas.

By the use of procaine as a vehicle, total anaesthesia is produced locally in a more satisfactory manner, allowing the necessary roentgenographic examinations for complete ligamentous tear. If such is noted, the usual plaster treatment is necessary. In the past we have used adhesive strapping, ethyl chloride, procaine, elastic bandage, and plaster boots, alone or in combination. Now hyaluronidase treatment allows a more effective anaesthesia with procaine and at the same time dissipates the hematoma and oedema. Other joint sprains have been treated with the same beneficial results, particularly those of the interphalangeal joints of the fingers.

Local Anaesthesia

We have been able to increase the efficacy of procaine and produce a more satisfactory local anaesthesia by the use of hyaluronidase. The spreading property of the enzyme causes a more rapid and extensive diffusion of the local anaesthetic. When trauma to a finger with a ring has occurred, the resulting swelling distal to the ring may cause severe pain and necrosis. Hyaluronidase and procaine should be injected locally at the site of the swelling. External pressure applied with a coiled string will allow the ring to be removed easily without pain or damage to the jewelry.

Fractures

In most fracture clinics a considerable number of closed reductions are performed under local anaesthesia, particularly in fractures about the forearm. Usually there is a twenty-minute lag between injection and adequate anaesthesia. By adding 500 TR units of hyaluronidase to the procaine solution, excellent anaesthesia is obtained in three to four minutes. Application of an elastic bandage for external pressure enhances the action of the hyaluronidase in dissipating the hemorrhage and oedema. With complete anaesthesia and the reduction of the surrounding swelling, the bone ends are more easily palpated and a more satisfactory reduction is possible. Hyaluronidase has been shown to remain effective for twenty-four hours, and it has been the authors' experience that at the end of that period after reduction, swelling has been less than in patients treated previously without the enzyme. The fundamental principles of limb elevation and finger motion are still of prime importance and must not be neglected. We now use this enzyme with procaine whenever we elect a closed reduction under local anaesthesia in fracture treatment.

On several occasions we have had the opportunity of injecting procaine and hyaluronidase into the fracture site of a patient who a few hours later had an open reduction. At the operation we were impressed with the absence of the usual signs of recent trauma. There was a startling lack of oedema and hematoma. Devitalized tissues were clearly demarcated and technically débridement was simplified and was more exact.

Early injection of the fracture site produces immediate relief of pain and thus improves the patient's morale and confidence in the manner of treatment.

Volkmann's Contracture

The typical problem of a severe supracondylar fracture of the elbow with the ever-present concern for adequate reduction obtained without circulatory impairment is common. The well known results of a Volkmann's ischaemic contracture are disastrous to both patient and doctor. It is not within the scope of this paper to discuss the etiological theories of this condition. The mechanical occlusion of the venous circulation with ischaemia and oedema results in subsequent fibrosis of the volar musculature. Undoubtedly vasospasm of the arterial tree plays a companion role. Immediate treatment is necessary if contracture is to be prevented. Hyaluronidase and procaine offer an effective non-operative method to relieve the subfascial tension caused by oedema and hemorrhage. The hyaluronidase rapidly disperses the offending fluid collection, and the procaine, which

FIG. 1-A

FIG. 1-B

Fig. 1-A: Two-year-old hemophiliac with large axillary hematoma of thirty-six hours' duration. Arm was fixed and radial pulse was barely discernible. Any attempt at passive motion caused extreme pain.
Fig. 1-B: Full range of motion was possible forty-eight hours after treatment. The pulse was strong. There was no pain.

under the influence of the enzyme diffuses through a much wider area, relaxes any degree of arterial spasm present.

CASE 1. J. R., a nine-year-old white boy, sustained a supracondylar fracture of the right humerus four hours before admission to the emergency ward. The elbow was markedly swollen and the antecubital fossa was obliterated by a brawny oedema. Any attempt at reduction and maintenance in the flexed position resulted in obliteration of the radial pulse. Accordingly, elevation with an olecranon wire was elected. Fifteen hundred TR units of hyaluronidase mixed in three cubic centimeters of one per cent. procaine was injected into and about the antecubital fossa and into the fracture site. The oedema diminished and the tissues about the elbow became soft. About thirty minutes after injection, it was possible to reduce and to hold the fracture in the flexed position, with a bounding radial pulse. The injections were repeated daily for three days to prevent the re-accumulation of fluid. A good result ensued.

Soft-Tissue Hemorrhage

Certain types of soft-tissue injuries result in considerable hemorrhage and swelling, depending upon size and site. Some of the hemorrhages may have delayed effects which are of the utmost importance. Myositis ossificans is a potential threat in any deep muscle hemorrhage, particularly if the extravasation lies close to bone and in a closed fascial space. This condition in the quadriceps and brachialis muscles, in particular, is prone to develop following direct trauma. The familiar charley horse of the football player always presents the threat of myositis ossificans as a complication. We have injected several such hemorrhagic areas with 1,000 TR units of hyaluronidase and one per cent. procaine with marked relief of tension and pain and the dispersion of the hematoma. The effect was constant and continued even after the anaesthesia produced by the procaine had worn off. We assume that, with this early dispersion, myositis ossificans is prevented, but we have not yet proved our contention. Of course we cannot predict in which patient this complication will develop, nor does every individual with a contused quadriceps seek medical treatment; but we think that a theoretically sound method of prevention is now available.

Soft-tissue hemorrhage alone may be a disabling condition in some instances, particularly when surgical release is impossible or impractical as in the following patient:

CASE 2. C. F., a two-year-old white boy of Italian extraction, a proved hemophiliac, was admitted to the Orthopaedic Hospital with a large axillary and subpectoral hematoma of thirty-six hours' duration (Fig. 1-A). When first seen, his right upper extremity was fixed at 90 degrees of abduction, and any attempt to move it caused extreme pain. The arm was oedematous to the finger tips and the radial pulse was barely discernible.

Fifteen hundred TR units of hyaluronidase were dissolved in eight cubic centimeters of one per cent. procaine and two cubic centimeters of the solution was instilled in each of the following locations: the axilla, in and beneath the deltoid anteriorly, in and beneath the pectoralis major muscle, and into the antecubital fossa. An elastic-bandage shoulder spica was applied. Twenty-four hours later, the patient was able to adduct the arm actively to within 45 degrees of the body. Most of the peripheral oedema had gone and the radial pulse was full and equal to that of the opposite side. A second course of injections was given and the elastic bandage spica was re-applied. At the end of forty-eight hours, the axilla was soft. The child could adduct his arm completely to his side (Fig. 1-B), and could reach above his head in all directions. Some fullness persisted about the shoulder girdle, but motion was painless and 90 per cent. of normal. There was no peripheral oedema.

Postoperative Hematoma

Unfortunately, the most careful surgeon cannot avoid an occasional wound hematoma, particularly when cancellous bone or a medullary cavity has been opened. Hematomata often develop after bone surgery and may give concern in the treatment. Fear of introducing infection makes one hesitant to re-open a wound. As an alternative treatment, postoperative hematomata of possible serious import have been injected with hyaluronidase, with the application and maintenance of firm external pressure. The results have been most impressive. A long-standing hematoma around which a fibrous wall has developed probably will not respond as well to this treatment as does one of recent origin.

In the surgical procedure of arthrodesis, it is necessary to expose considerable cancellous bone which, on removal of the tourniquet, bleeds considerably, despite pressure dressings. A considerable amount of this blood collects locally and may be a source of delayed skin healing and constriction of lymphatic drainage distal to the fusion area. This is particularly true in arthrodeses of the wrist, ankle, and subtalar joints. In an attempt to diffuse this hematoma and to prevent local accumulation, we have instilled hyaluronidase into the deeper layers of the incision at the time of closure. It is not possible in such a procedure to present statistical evidence of the results, for there are no measurable standards for comparison. In those cases in which this has been done, however, impaired circulation seems to have been less of a problem and ecchymosis more widespread. Due to this absence of local collections, tissue necrosis and hematoma did not appear. It is too early to say whether this method of treatment will consistently be beneficial, but the prospects so far are encouraging.

In surgery involving the opening of the knee joint for meniscectomy and other intra-articular procedures, we have instilled 1,000 TR units into the joint when closing it. The apparent reduction of postoperative joint distention was marked.

Hemophilic Hemarthrosis

Acute hemophilic hemarthrosis is a difficult and discouraging condition to treat. The effects of repeated hemorrhage into a joint cavity are well known. The treatment of late flexion contractures and arthritis demands prolonged hospitalization with wedging casts and splints, followed by physical therapy, and even then the results are not remarkable. Previously, the usual treatment of an acute hemarthrosis in hemophilia has consisted of sedation, splinting, and, after all pain and danger of bleeding had subsided, cautious physical therapy. This may have required several weeks of hospitalization before the original range of motion was restored, and often there was residual limitation. We have injected hyaluronidase and procaine into these acutely painful joints[2]; within forty-eight hours the previous range of motion has been restored and pain has been eliminated.

The method is, in brief, as follows: When a hemophiliac appears with an acute hemarthrosis, the clotting time and other routine laboratory data are obtained. Plasma or fresh blood is given to lower the clotting time. The joint is entered with a small bore needle in the usual manner, and three to four cubic centimeters of the dark viscid blood is removed. One thousand TR units of hyaluronidase are then mixed with procaine in the amount equal to that of the blood withdrawn. This is injected into the joint and a snug

elastic bandage is applied. No treatment other than bed rest is necessary. When the patient is re-examined in twenty-four hours, pain is usually absent and the range of motion is much greater. Occasionally, a second injection is necessary. After forty-eight hours, the patient can walk without pain or has free use of an upper extremity and may be discharged.

We have had nineteen good results, with a restored range of painless motion in forty-eight hours. One failure resulted from cessation of treatment because of joint reaction, thought possibly to be due to infection. This was not verified and the joint later recovered. The rapid restoration of a normal range of motion precludes stiffness; but perhaps even more important is the early restoration of normal synovial fluid to the involved joint and thus return of the normal nutritional source of the articular cartilage, thereby forestalling or preventing the degenerative changes which lead to crippling arthritis.

In conclusion, we have found that hyaluronidase has provided us with a definite therapeutic aid in orthopaedic cases in which hemorrhage and oedema have been obstructive factors in the path of satisfactory treatment.

NOTE: The authors wish to express their appreciation to Wyeth Inc., Philadelphia, Pennsylvania, for their generous donations of the hyaluronidase used in this study.

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DISCUSSION

DR. LEE C. SCHLESINGER, NEW ORLEANS, LOUISIANA: The authors have proposed a new substance for our armamentarium. In itself, it is not a therapeutic agent, but it acts as a catalyst for several aids in healing. Since its appearance on the commercial market, we have made use of it in hospital and office practice and we believe that the findings of Dr. MacAusland and his associates are valuable and helpful.

It has been our observation, in the instances when we have used hyaluronidase, that it has performed its tasks without detriment to the late healing or local tissue reaction. We have used it under the following circumstances:

1. In donor bone-graft sites, such as the ilium, in order to prevent hematoma and serous drainage;

2. As an adjunct in local novocain injections for minor fractures and for trigger-point areas of the back and subdeltoid regions;

3. In suppurative arthritis of the joints in conjunction with penicillin therapy. In the first instance, the iliac area showed less swelling and less tenderness, and the patient appeared to move about more freely, whereas in our previous experience the condition of this area has usually been the cause of prolonging the patient's stay in bed. Hematomata are not usually present and serous drainage occurs to a lesser degree.

When combined with novocain for metacarpal, metatarsal, finger, and toe fractures, the effect of the anaesthetic is more immediate; less of the drug is required; and the comfort afterward is more assured. However, I do not embrace its use in ankle sprains, as do the authors, since it does not appear physiological to allow weight-bearing on these traumatized tissues. I cannot agree that the reparative process of a ligamentous tear is hastened by weight-bearing and motion, even though this drug is used.

When the aspiration replacement technique of penicillin therapy has been used in suppurative joints, we have observed that, although the character of the joint fluid is changed and organisms disappear, the bulk of synovial fluid returns, which necessitates re-aspiration, although infection has been combated. With the addition of hyaluronidase to our penicillin injections, the factor of excess fluid is materially aided, and there does not appear to be any inhibitory effect on the healing process.

We have not recently encountered impending Volkmann's contracture, and therefore cannot comment on the therapeutic assistance of this drug in that condition. The speaker's enthusiasm for the prevention of

(*Continued on page 680*)

FRACTURE OF THE CARPAL NAVICULAR (SCAPHOID) BONE

An End-Result Study in Military Personnel *

BY JOSEPH S. BARR, M.D., WILLIAM A. ELLISTON, M.D., HENRY MUSNICK, M.D., THOMAS L. DELORME, M.D., JOSEPH HANELIN, M.D., AND ARTHUR A. THIBODEAU, M.D., BOSTON, MASSACHUSETTS

Fracture of the carpal navicular is a frequent injury in young adult males; and, as might be anticipated, it was a common cause of disability in Military Service during World War II. This study was undertaken in order to determine the incidence of this fracture in the Armed Forces, the amount of disability resulting from it in both united and ununited fractures, the factors predisposing to non-union, and the various methods of treatment of non-union. Although it was originally planned to study at least 100 cases of united as well as of ununited fractures with a minimum elapsed time since injury of five years, it proved possible to obtain the names and addresses of only seventy-one veterans and of these only fifty were available for study. Forty-four of this latter group reported for study; six refused to come in. The chief obstacle to locating veterans with this fracture lay in the fact that punch-card coding in the Army files included only a 10 per cent. sample of the total injuries occurring in a single year.

Although the small number of patients available made a statistical study of no value, a clinical study was undertaken in the following manner: Each man was studied by a professional team consisting of an orthopaedic surgeon, a roentgenologist, a psychiatrist, and a doctor interested in muscle physiology. A careful history was taken and compared with the information recorded in the health and hospital records. This was followed by a physical examination, psychiatric evaluation, ergographic studies, and detailed roentgenographic examinations.

The orthopaedic investigation including the history and physical examination revealed that nearly 90 per cent. of the fractures in this series occurred in veterans under the age of thirty years, the youngest being eighteen and the oldest forty-seven. Of the total group, thirty-nine were injured in Military Service, while five had sustained the fracture prior to Military Service and had resulting non-union. There was no apparent correlation with the type of duty. Of the thirty-nine receiving their fractures during Military Service thirty-one (thirty-two wrists) had primary union and in eight (nine wrists) non-union developed. These nine non-unions combined with the five men with established non-union prior to Military Service gave a total of fourteen non-unions diagnosed while the men were on active duty. No one with primary union was surveyed from the Service because of this injury, while of those with non-union, six or approximately 50 per cent. were discharged because of wrist disability and seven completed their terms of Military Service with some handicap. Surgical treatment resulted in union in two of these seven with non-union. Of the five with non-union prior to Military Service, four were discharged and one was treated successfully with bone-grafting.

Although the left wrist was more frequently injured in this series than the right, there was no statistically significant relationship between the side injured and the dominant hand.

The mechanism of injury was a fall on the outstretched hand in thirty-one cases, a blow with the fist clenched in three, a twisted wrist in three, and hyperflexion of the wrist

* This study was carried out at the Massachusetts General Hospital under contract from the Veterans Administration upon recommendation of the Committee on Veterans' Medical Problems of the National Research Council. This is a condensed version of the report submitted to the National Research Council: C.V.M.P. Project No. 32, V. Am. Project No. 23325.

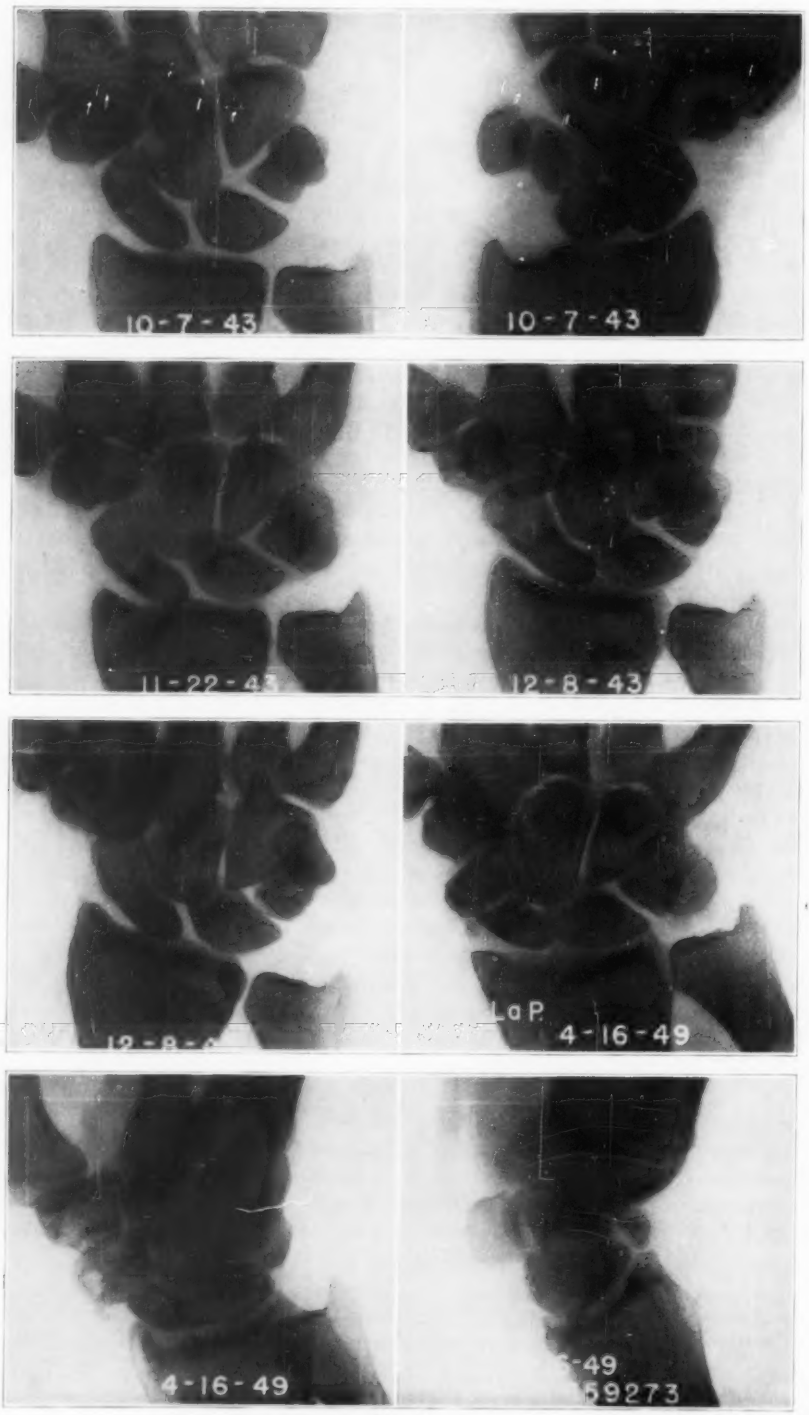

FIG. 1

No. 659273. Development of non-union. Age at the time of study: twenty-eight; age at injury: twenty-two.

(*Continued on page 611*)

(*Continued from page 610*)

October 7, 1943. The patient sustained an acute fracture through the waist for which the wrist was immobilized in a plaster cast with the thumb incorporated and the wrist in dorsiflexion. The cast was worn for eight and a half weeks, being changed only once.

November 22, 1943. Evidence of aseptic necrosis, proximal fragment.

December 8, 1943. Fracture line is less distinct, but the proximal fragment remains relatively dense.

April 16, 1949. Non-union, fragmentation, dorsal angulation of the fragments, cyst formation in the distal fragment, and mild traumatic arthritis are seen on the roentgenogram. Two small osseous bodies have formed along the anterior lateral aspect of the fracture. A_4 F_1 E_3.*

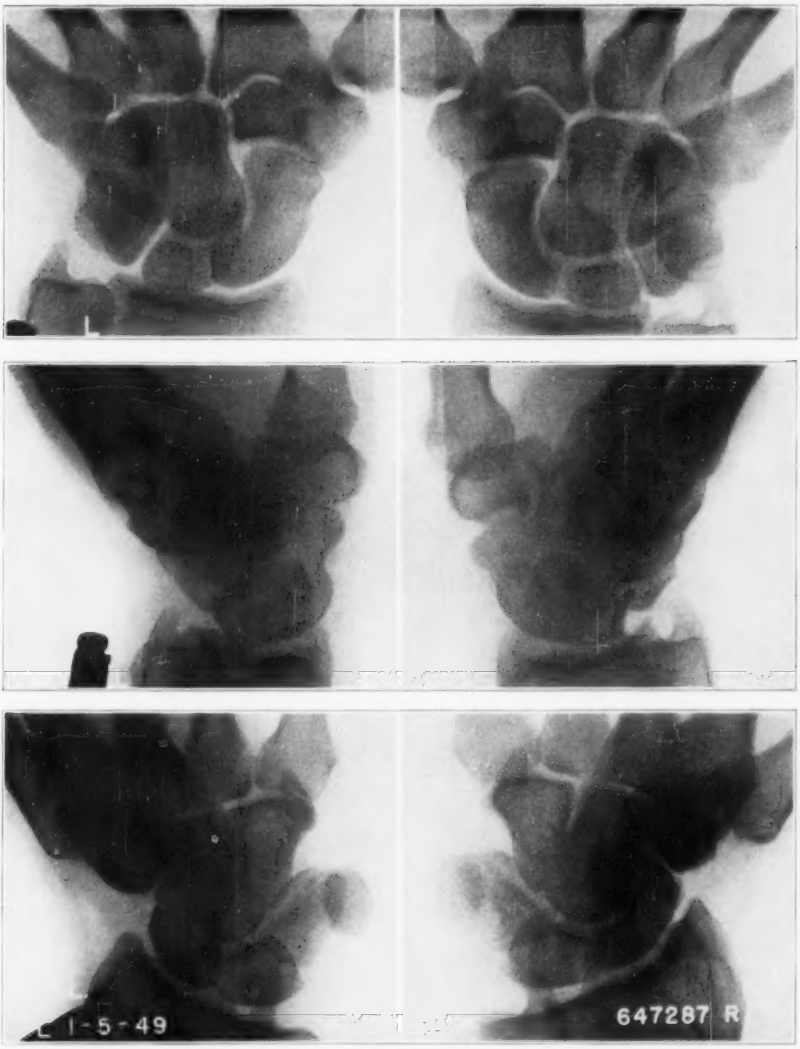

FIG. 2

No. 647287. Successful drilling operation, right. Age at the time of study: twenty-six; age at injury: twenty.

Inadequate immobilization by means of an anterior plaster splint for four weeks led to non-union. Ten months after injury drilling operation was done followed by immobilization for seven months. The navicular shows increased density of the mid-portion with minimal dorsal angulation. Slight traumatic arthritis is also shown. A_4 F_3 E_4.

* In each instance, the result was evaluated, according to the method in use at the Massachusetts General Hospital, from three separate viewpoints: anatomic restoration (A), functional recovery (F), and the effect upon economic ability (E). Each of these three was graded on a numerical basis ranging from 4 (87.5 per cent. to 100 per cent.) to 0 (12.5 per cent. and below).

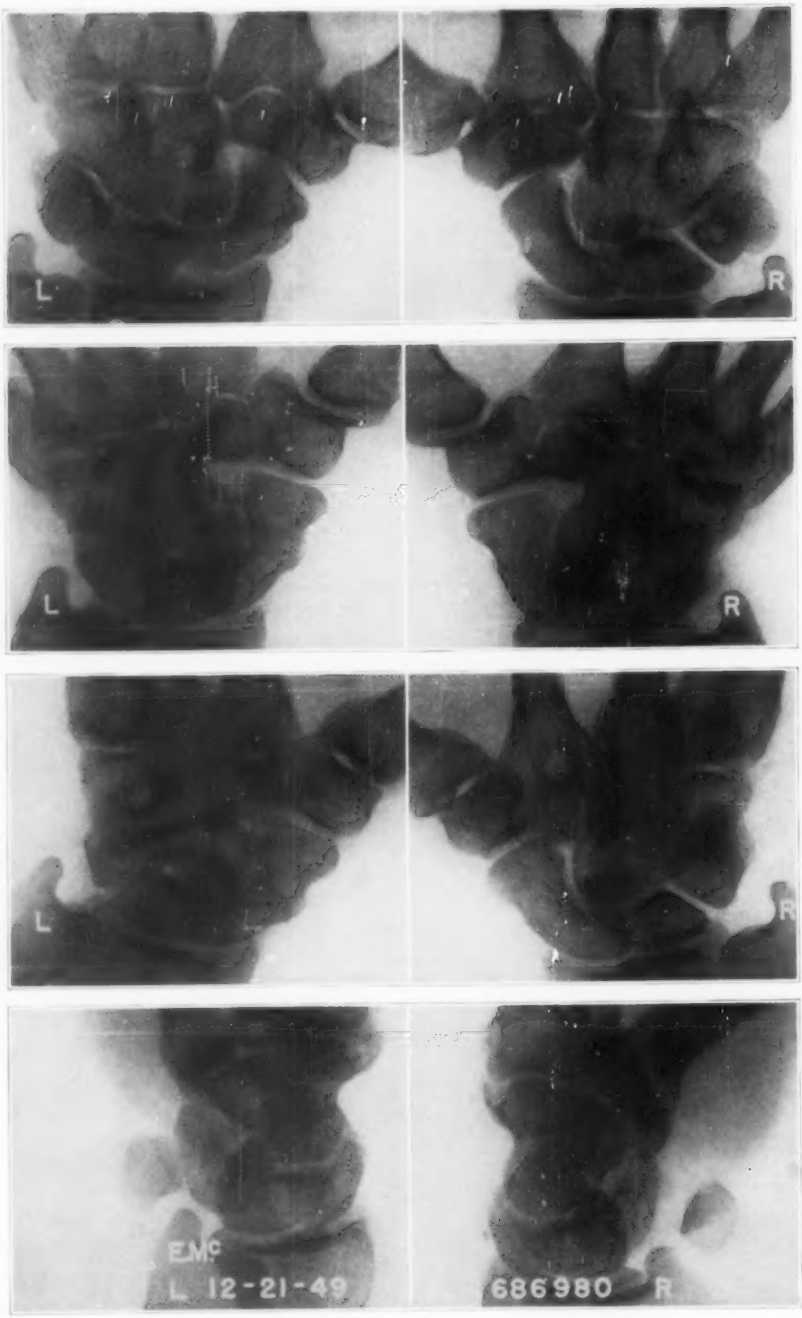

FIG. 3

No. 686980. Healed fracture, left wrist, with minimal displacement. Age at the time of study: twenty-six; age at injury: twenty-three.

Patient fell on acutely flexed wrist. The fracture was immobilized for an adequate period. Roentgenogram shows radial and distal angulation at the waist of the left navicular. The right wrist is normal. A_2 F_4 E_4.

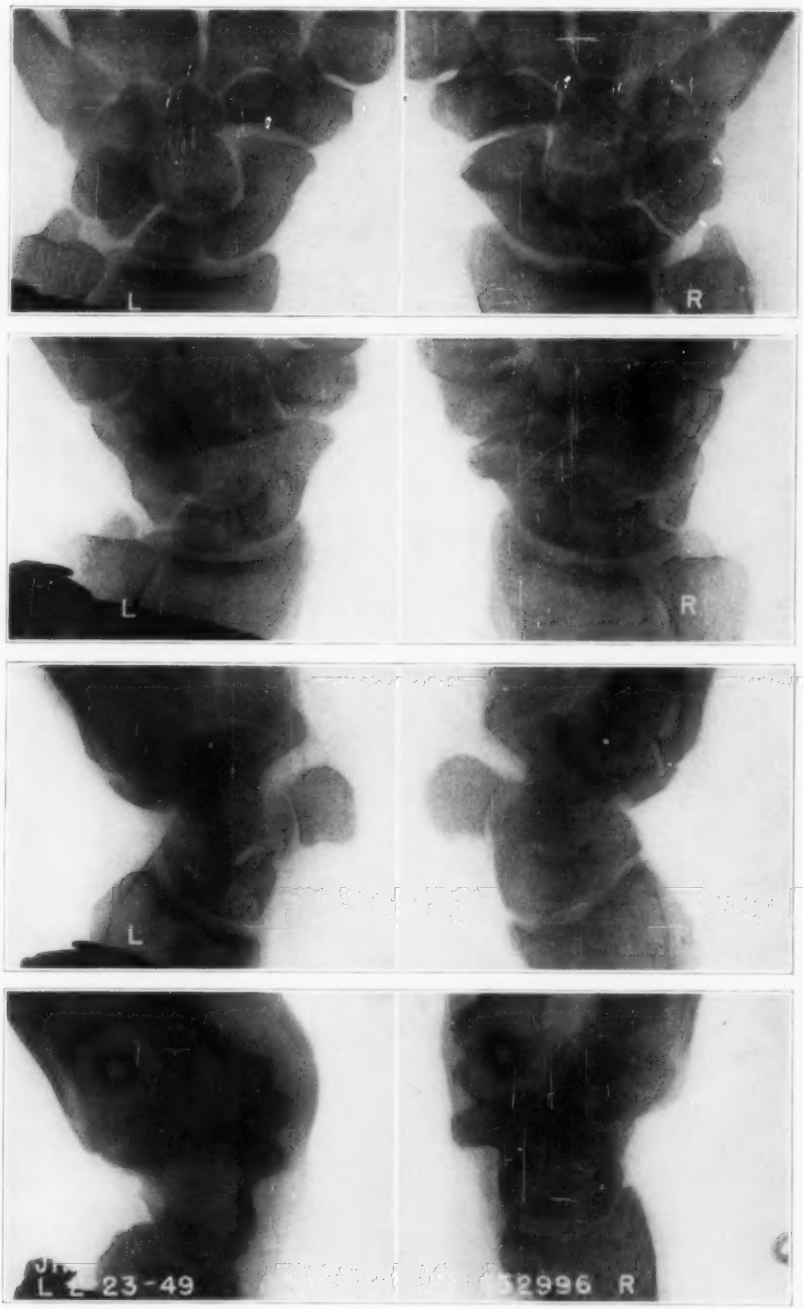

FIG. 4

No. 652996. Successful bone graft, right. Age at the time of study: twenty-nine; age at injury: twenty-five.

Fracture was not detected until non-union had developed. The non-union was treated by a tibial graft and the insertion of multiple bone chips two years after injury. Union was evident four months later. Slight sclerosis of the proximal half of the right navicular occurred. There was minimal traumatic arthritis and slight osteoporosis of the wrist bones. A_4 F_2 E_4.

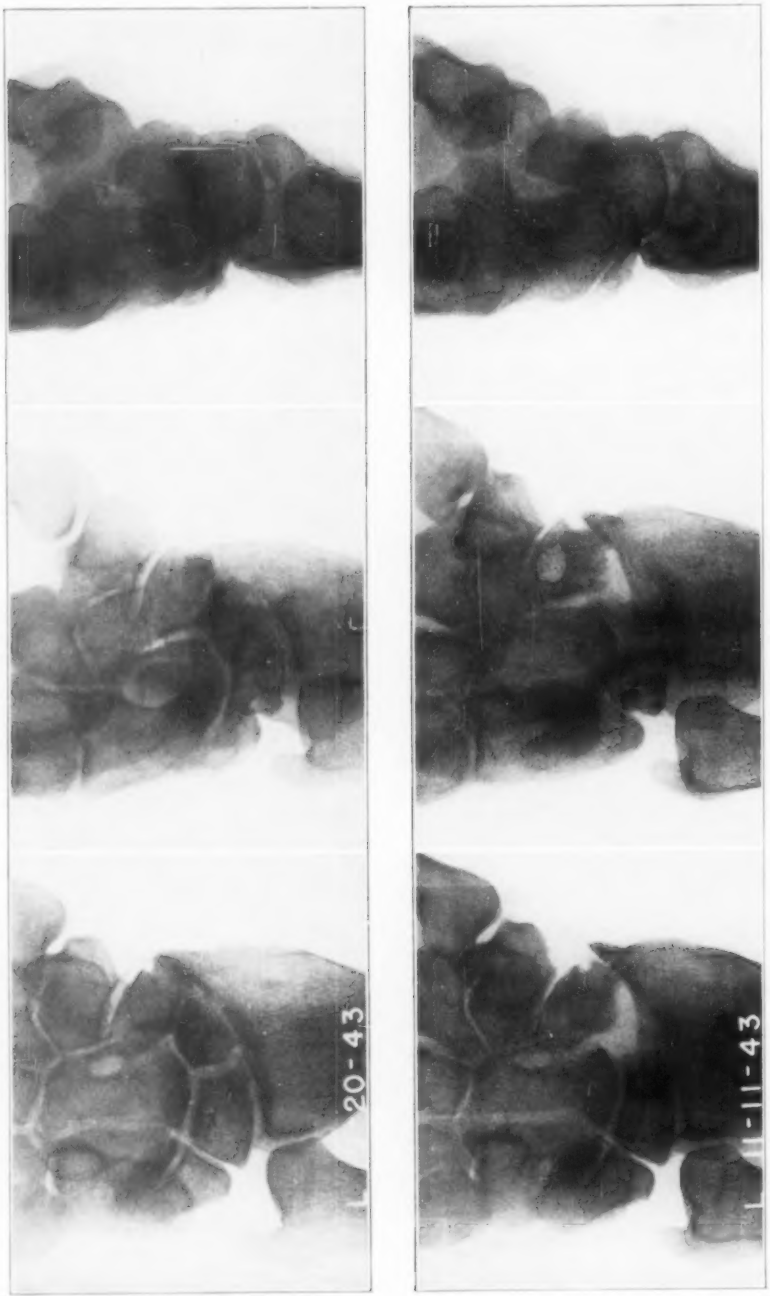

FIG. 5-A

No. 655632. Resection of proximal fragment. Age at the time of study: fifty-two; age at injury: forty-seven. The proximal fragment was resected about four months after injury when non-union was discovered. November 11, 1943. Roentgenograms made one month after the operation.

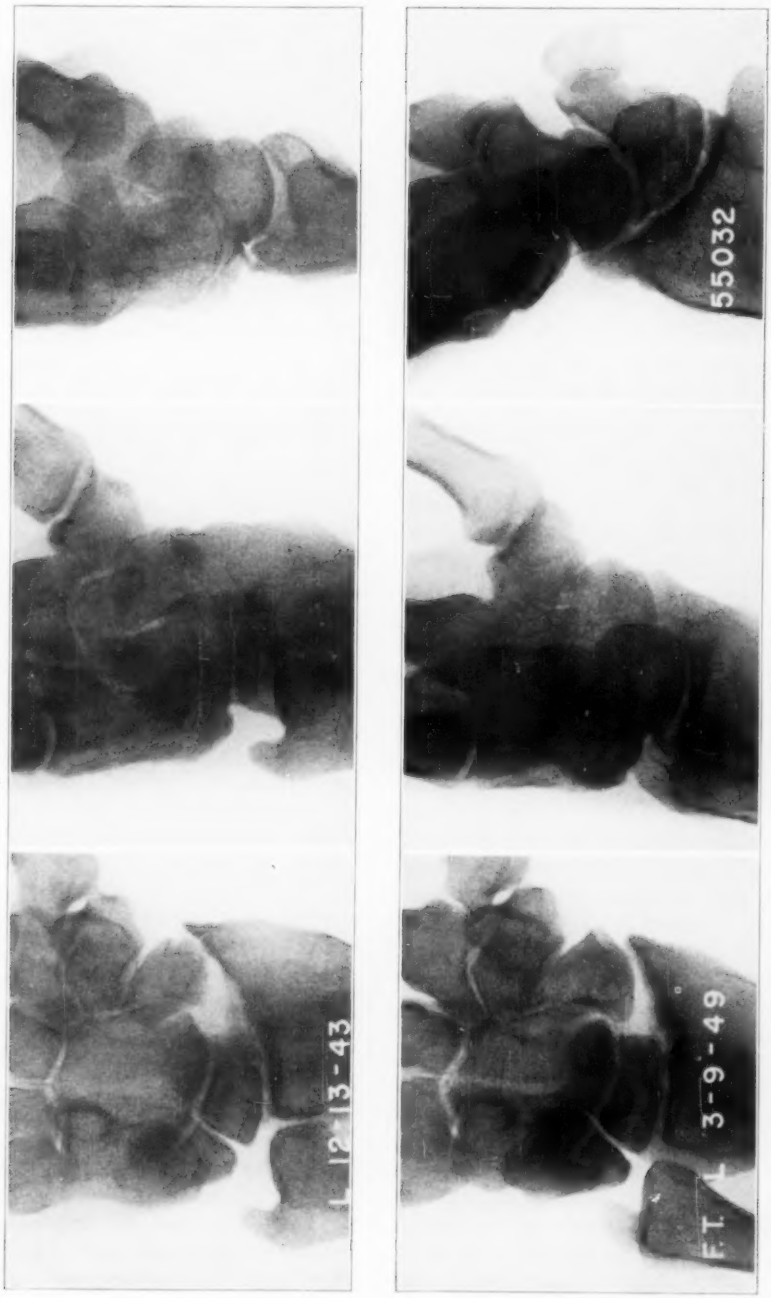

FIG. 5-B

December 13, 1943. Roentgenograms made two months after the operation.
March 9, 1949. Final roentgenograms show considerable smoothing of the residual fragment. Its lower pole has rotated medially. There is traumatic arthritis and osteoporosis, as well as a small cystic area in the capitate. A, Fig 5-e.

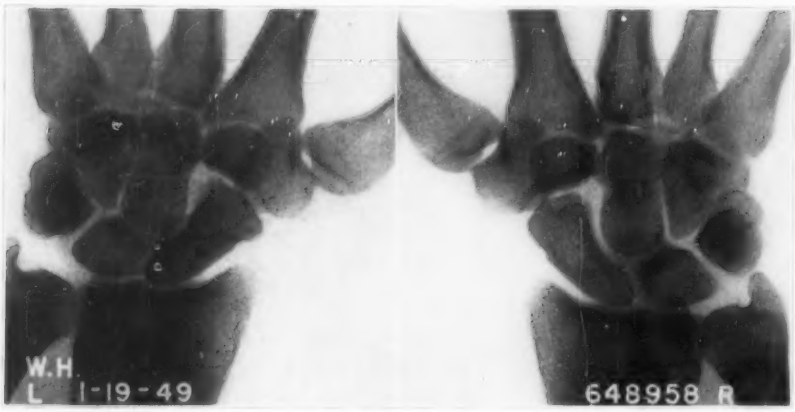

FIG. 6

No. 648958. Healed fracture, left. Age at the time of study: twenty-seven; age at injury: twenty-three.

The fracture of the left navicular was immobilized for only two weeks after injury, yet union occurred. The sclerotic band through the waist of the left navicular may be residual to fracture or may be normal ridge. The right wrist is normal. A_4 F_4 E_4.

in one. The mechanism was not known in eight. Most of the injuries were incurred during organized athletics; only three occurred during combat.

The signs and symptoms found in this study did not differ from those found in other series; these were pain, weakness, swelling, limitation of motion, and local tenderness.

Of the thirty-nine men injured while in Service, twenty-nine were x-rayed within two days of their accident. The remaining ten either failed to report for examination early or were told they had "sprained wrists". The diagnosis was made within one week of injury in thirty-one wrists and in all but two of these primary union was obtained. One non-union occurred even though the wrist had been immobilized in plaster for eight and one-half weeks (Fig. 1), while the other was immobilized only four weeks. From the data available, the causes for non-union appeared to be (1) too short or inadequate immobilization and (2) delay in treatment for one reason or another (failure of the patient to report injury, erroneous diagnosis of a sprain, and combat conditions). The standard plaster gauntlet with the thumb included and the wrist in the cock-up position was the usual form of immobilization and gave good results, provided it was applied early and was maintained until union was present as shown by x-ray.

The end results in this series showed that among the thirty-one men with primary union (thirty-two wrists), thirty wrists showed an almost perfect anatomical result by x-ray, while three showed mild displacement of the fragments (Fig. 3). None of these patients had permanent impairment of earning power and only five (16 per cent.) had any impairment of function. The functional deficit was mild and included tenderness in three cases, a "clicking" sensation in one, diminished grip in four, and some loss of motion in three. Among the fourteen veterans (fifteen wrists) with established non-union at this end-result study, non-union developed in one after discharge. Six had essentially no treatment; three were treated unsuccessfully with plaster-cast immobilization; and six were treated surgically. Only two operations were successful; one consisted in drilling the fracture line, followed by seven months' immobilization (Fig. 2); the other was the insertion of a tibial-bone graft which resulted in union in four months (Fig. 4). Among the failures were one patient in whom excision of the proximal fragment had been done (this resulted in the poorest wrist function of any wrist examined in this series) (Figs. 5-A and 5-B), one in whom the fracture line was drilled and the wrist was immobilized for only two months, and two patients whose fractures had been treated by the insertion of tibial-bone grafts.

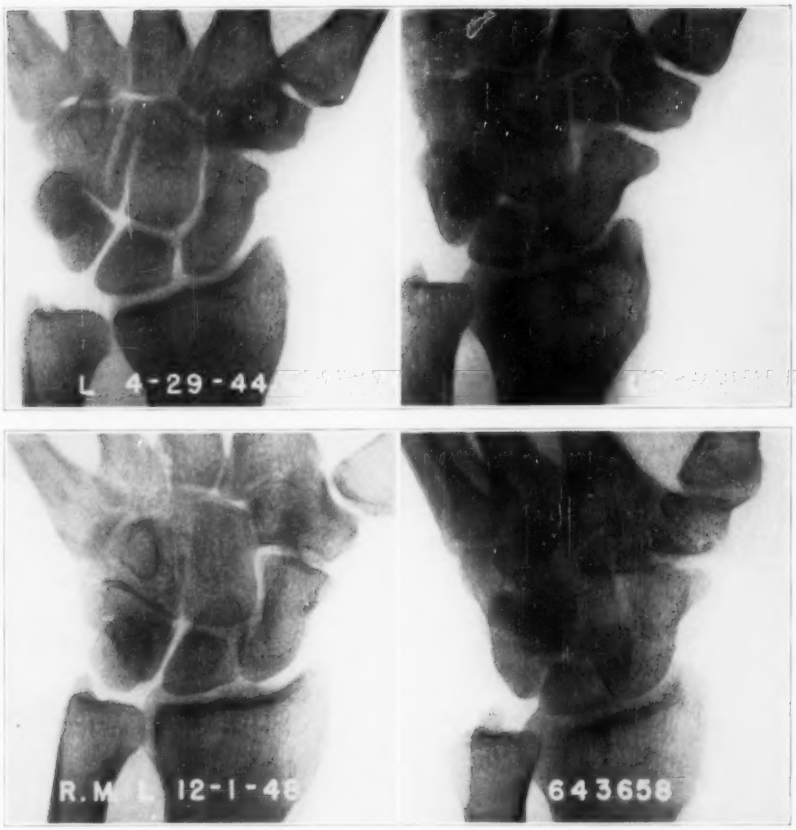

FIG. 7

No. 643658. Fracture of the tuberosity of the left navicular. Age at the time of study: twenty-six; age at injury: twenty-two.

The wrist was immobilized for nine weeks after injury. The fracture of the tuberosity seen in the roentgenograms made on April 29, 1944, is shown to be healed in those made on December 1, 1948, but there is minimal displacement. A_4 F_4 E_4.

In the roentgenographic studies of these veterans, multiple views were employed of both wrists in order to determine the position of the healed fragments. Although all views were considered helpful, those giving maximum information were (1) the postero-anterior view with the wrist in ulnar deviation, (2) the oblique postero-anterior view with the hand in neutral, medial side down, and the forearm in pronation of 45 degrees, and (3) the oblique antero-posterior view with the hand in neutral, medial side down, and the forearm in supination of 45 degrees.

Among the forty-four veterans (forty-six fractures) studied, twenty-four fractures were on the left, eighteen on the right, and two were bilateral. Twelve showed non-union and in one the proximal fragment had been excised. The fracture was located in the waist in twenty-nine cases, in the tuberosity in three, and in the proximal third in three. The location could not be determined in eleven. Where primary union had occurred, frequently no residuum of the fracture could be visualized; often slight coarsening of the trabeculae or a sclerotic band at the site of injury was the only evidence of injury (Fig. 6). In three there was slight displacement (Figs. 3, 7) and in one instance some evidence of osteoporosis. The two fractures uniting after surgical intervention also showed displacement (Figs. 2, 4). These were the only wrists showing evidence of both traumatic arthritis and osteoporosis in the group with union.

In the twelve instances of non-union (two in the proximal third, ten in the waist) the following changes were noted:

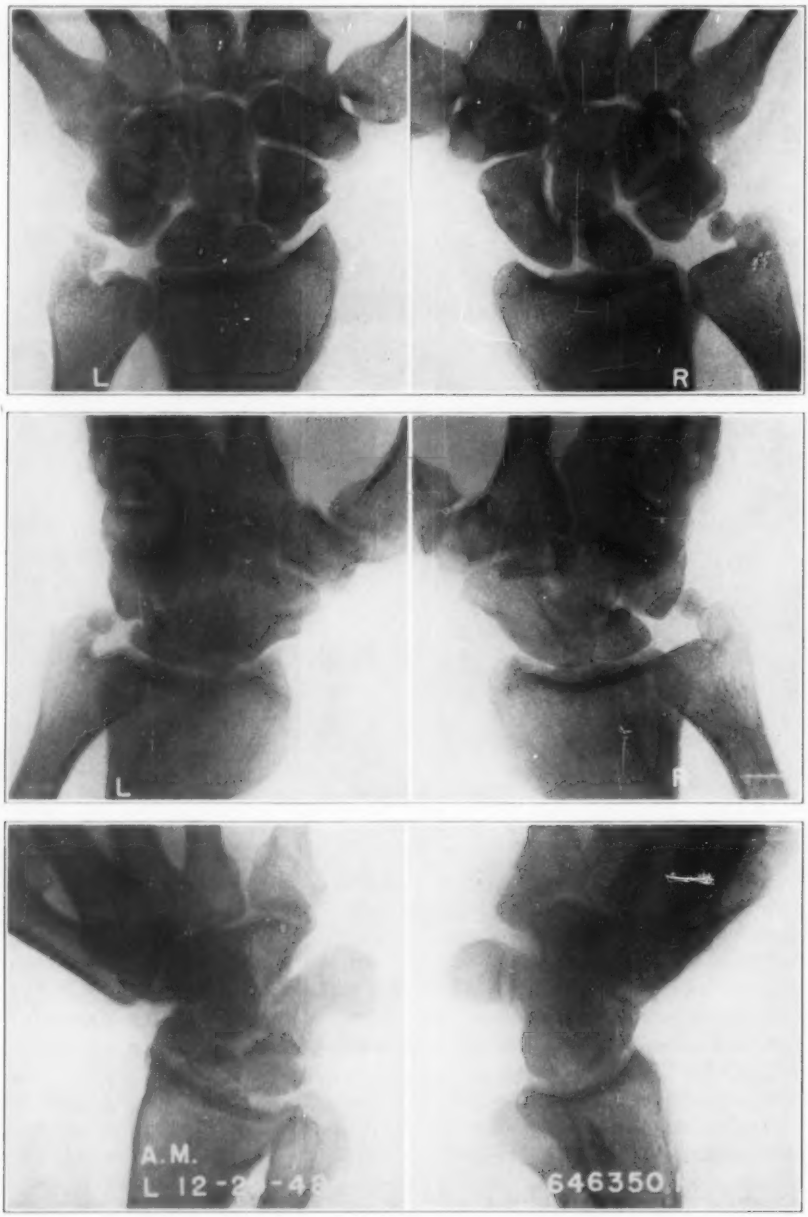

FIG. 8

No. 646350. Non-union, left. Age at the time of study: thirty-one; age at injury: twenty-six. The patient did not report the original injury. One to two years later, he sustained another injury to the same wrist at which time the diagnosis of ununited fracture was made. Although immobilization was maintained for ten weeks, union did not occur. The roentgenograms show a fracture through the proximal third with fragmentation, dorsal angulation, and traumatic arthritis. The right wrist is normal. A_0 F_3 E_4.

1. Fragmentation in two cases (Figs. 1, 8), apparently the result of continued use in the presence of non-union and not comminution of the fracture with initial injury;

2. Displacement (all cases) consisting of dorsal angulation in ten (Fig. 9) and eventual radial and distal displacement of the proximal fragment in two (Fig. 10);

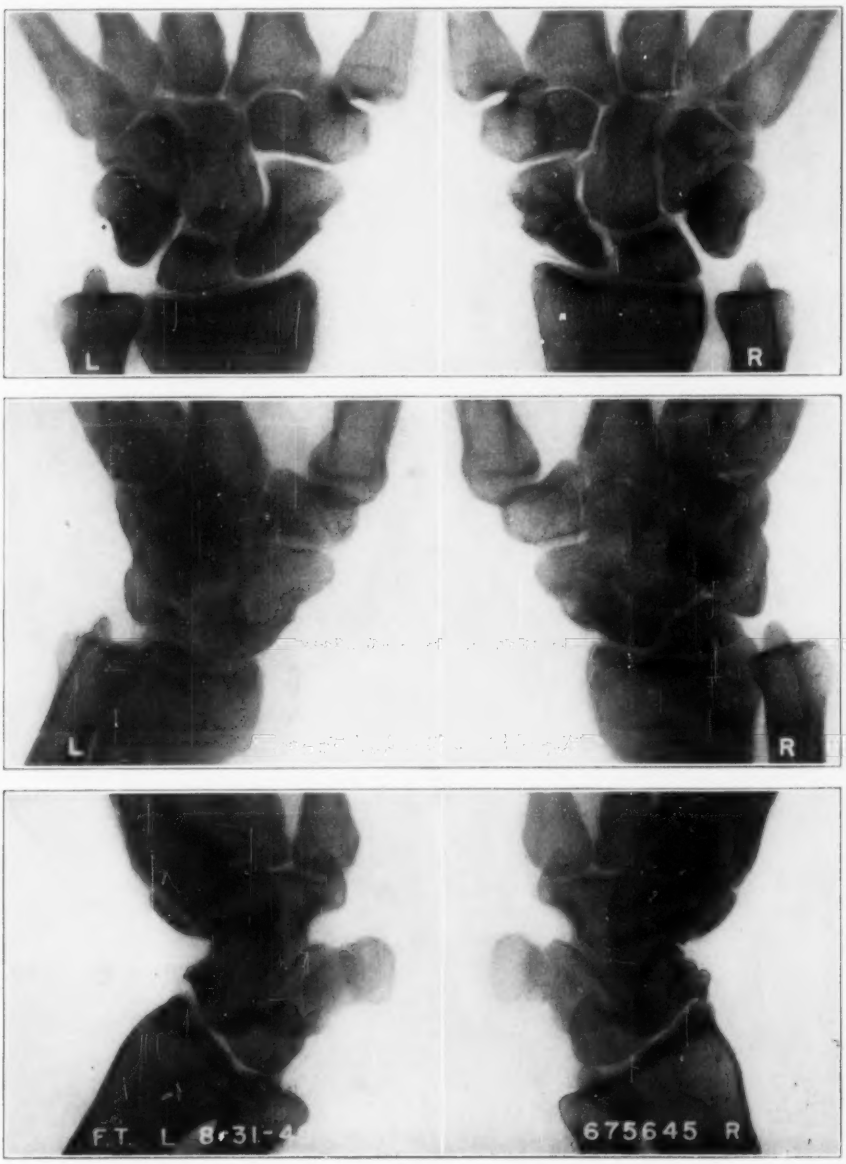

FIG. 9

No. 675645. Non-union, right. Age at the time of study: thirty-three; age at injury: fifteen or sixteen.

Patient had received no treatment. As seen in the roentgenograms there is dorsal angulation of the fragments, aseptic necrosis of the proximal fragment, cyst formation, and traumatic arthritis, as well as the formation of a small ossification in the joint at the tip of the radial styloid. Linear density through the waist of the left navicular could be a normal ridge or the result of the old injury. $A_0 F_4 E_2$.

3. Aseptic necrosis in six cases — of the proximal fragment in four (Fig. 1), of both fragments in one, and of the distal fragment alone in one. (The two latter cases may have represented reactive or traumatic sclerosis);

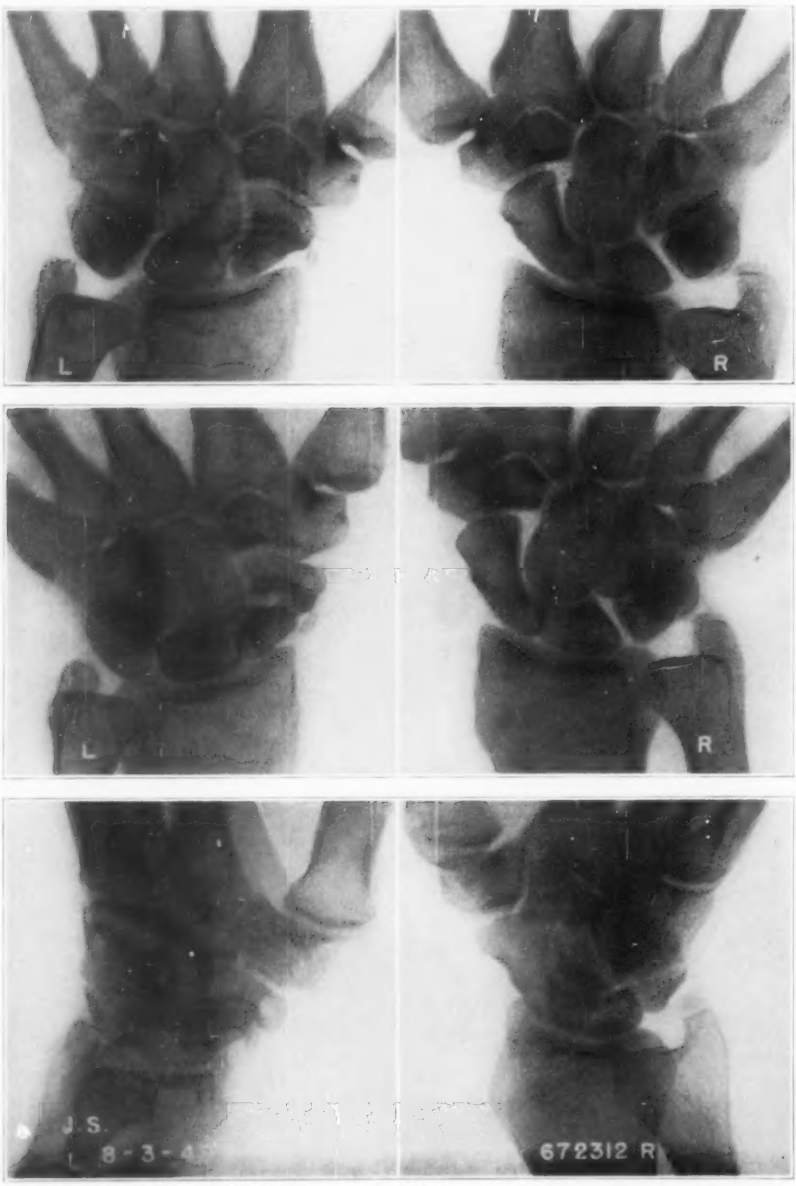

FIG. 10

No. 672312. Non-union, left. Age at the time of study: forty-six; age at injury: unknown. Patient apparently had had an ununited fracture before his entry into the Service. When he reported a sore wrist, his wrist was treated with immobilization in a plaster cast for four weeks without benefit.

The roentgenograms show sclerosis at the fracture margins, cyst formation, radial and distal displacement of the proximal fragment, and traumatic arthritis. Separation of fragments on ulnar deviation and the osseous body lateral to fragments should be noted. A_5 F_2 E_4.

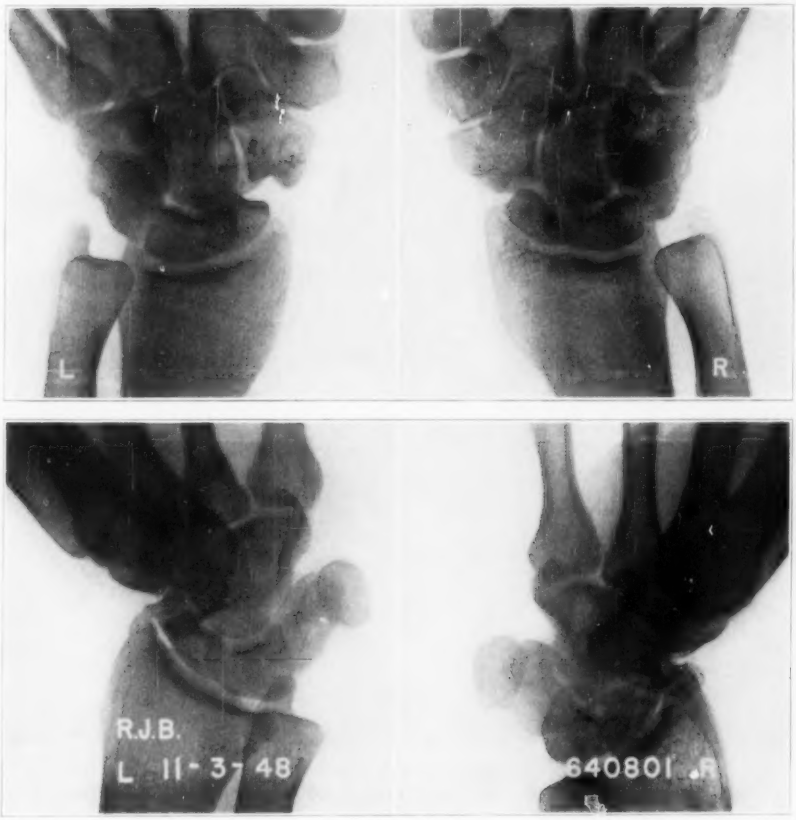

FIG. 11

No. 640801. Non-union, bilateral. Age at the time of study: twenty-seven; age at injury: unknown.

The patient's injury probably antedated his entry into the Service. There is a wide gap between the fragments and a small fragment dorsally on both sides. There is dorsal angulation of the fragments bilaterally. On the left, sclerotic fracture margins and cyst formation in the distal fragment and in the capitate are seen. There is traumatic arthritis bilaterally. The symmetrical changes seen in both wrists raise the possibility of congenital tripartite naviculars. A_0 F_2 E_3.

4. Sclerosis of the fracture margins in six cases (Figs. 9, 10);

5. Cyst formation in seven cases—six in the distal and one in the proximal fragment. (One wrist showed cysts in both the capitate and the greater multangular) (Fig. 11);

6. Osteoporosis in three cases (Fig. 4);

7. Traumatic arthritis to a greater or lesser degree in all cases (Fig. 9).

The work capacity of each subject's hand was evaluated by means of a specially designed ergograph. The instrument was so constructed that two pairs of parallel, vertical posts projected from the top of a table at which the subjects sat (Figs. 12, 14). The movable posts of each pair were connected by a system of gears with a large pulley to the circumference of which two heavy weights were attached (Fig. 13). At rest, the cable and weight exerted no torque, but as the posts were approximated by the patient's grip the large pulley was rotated, causing the weights to travel upward and outward on the circumference of the pulley. As a result, a progressive increase in torque was exerted by the weight. This apparatus made it possible to test both hands simultaneously or separately. The rate of contraction and relaxation was regulated by a metronome, while the strength of each contraction was recorded by an ink tracing on a moving paper (Fig. 14). The work

done could thus be measured in inch-pounds. Each test was run for two minutes, since beyond this point a fatigue level or plateau was reached which the subject could maintain indefinitely. The rate and rhythm of contraction was set so that there were approximately forty-two to forty-four contractions per minute, the periods of contraction and relaxation being equal. Two tests were given at fifteen-minute intervals. Since no significant difference in the work capacity of the two runs was found, only the data from the first run were used. Tests on seven normal young males indicated that the mean work capacity of the dominant hand was 5.5 per cent. greater than that of the opposite side. However, since

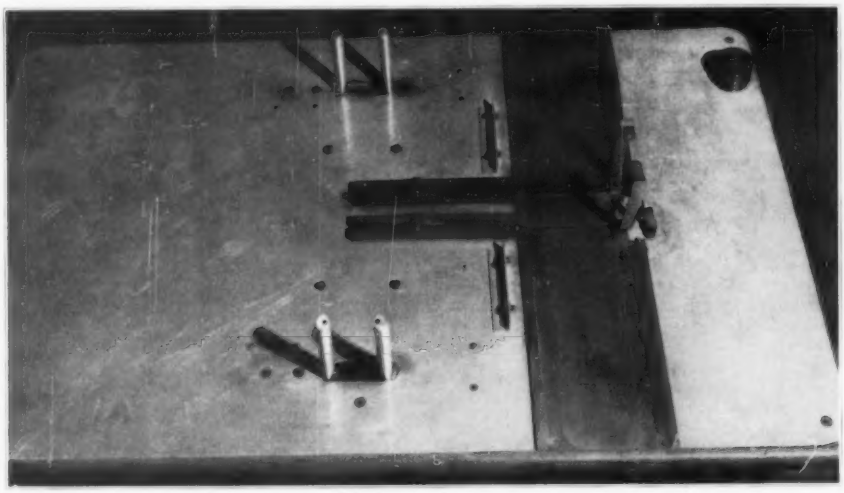

FIG. 12

View of the top of the ergograph. Paper is not in place nor are the ball-point pens. The switch in the upper right-hand corner is used to turn on or off the motor which moves the paper.

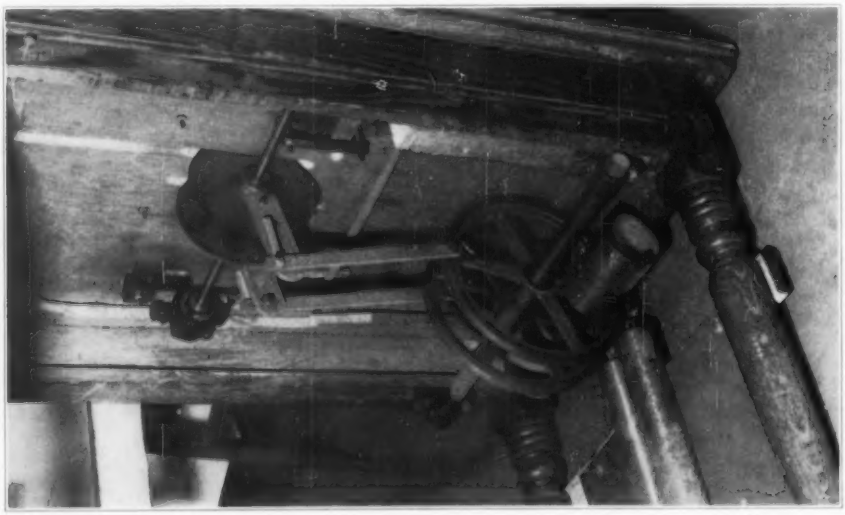

FIG. 13

View of the undersurface of the ergograph showing gear mechanism and weights. As shown, the vertical posts are approximated so that the weights attached to the large pull-up are exerting maximum torque.

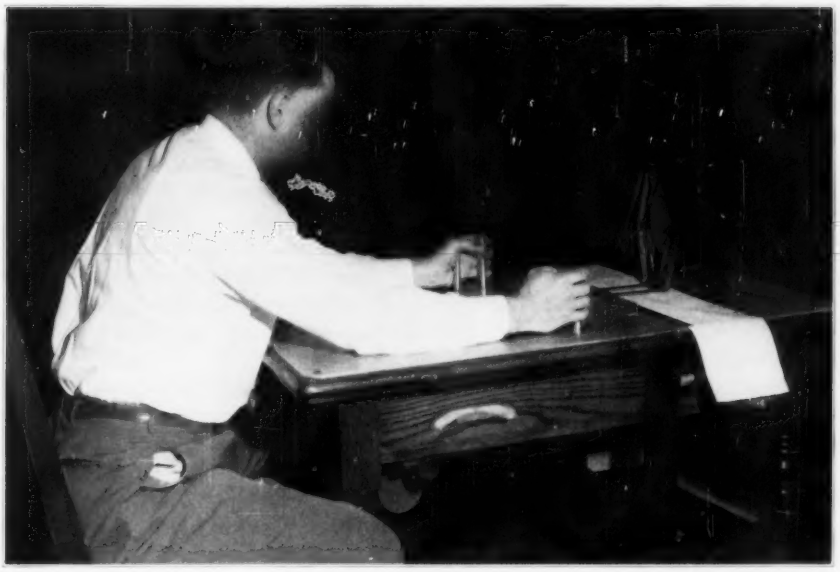

FIG. 14

A patient is shown sitting at the ergograph in position for testing. Note vertical posts, moving paper, ball-point pens adjusted to record contractions, and the metronome. The motor to move the paper is in a rack on the underside of the table.

there was a 10 per cent. error inherent in the apparatus for various technical reasons, the effect of hand dominance could be disregarded. The data were recorded as a percentage of normal, normal being considered to be the work capacity of the subject's uninjured hand.

The ergographic contours were strikingly consistent in normal hands. There was an initial treppe effect of several successive spikes, then spikes or contractions of fairly constant or slightly decreasing amplitude for at least a one-half minute, after which there was a rapid but regular decline in spike amplitude until a plateau was reached where the mean spike amplitude was constant indefinitely, representing the aerobic contraction phase.

There were thirty-eight subjects with satisfactory ergograms. Of these, sixteen were discarded because the subjects' attitudes either were not recorded or could not be evaluated. Among the veterans with excellent results there was a striking correlation between the ergographic and the functional and anatomical ratings as determined by orthopaedic and roentgenographic examinations. However, in the poorer results there was little or no uniformity among the three types of rating. No explanation for this could be found. The ergographic test is one of maximum effort, performed under stress with attendant pain, and psychological factors which are rarely if ever present otherwise. It may be for this reason that this test bears no relationship to the other methods of evaluation which are based on an arbitrary rating of strength, motion, ability to work, and subjective symptoms. In cooperative subjects the ergographic test proved an accurate method of evaluating work capacity and showed the influence or lack of influence of such factors as pain, weakness, and limitation of motion. However, it did not reveal the responsible factor for reduction in work capacity when two or more of these factors were present. Furthermore, this test revealed previously undetected loss of work capacity caused by minimal amounts of pain, weakness, and loss of motion, or conversely the absence of any reduction of work capacity in spite of the presence of minimal disabilities.

In uncooperative patients the contour of both the normal and injured hands was

characteristically irregular. This was in contrast to the painful cases in which the ergograms were smooth, resembling the normal contour, except that the total amount of work done was reduced (that is, in diminished height and duration of contractions). In about one-half of the uncooperative patients the ergogram of the normal hand tended to follow that of the injured hand. This was not necessarily true in the cooperative patient. It was thus possible to detect work-capacity reduction with considerable accuracy on the basis of poor cooperation or "malingering" rather than pain, weakness, or limitation of motion.

The psychiatric study of these patients was undertaken to elucidate the role of personality in (1) the production of fracture of the carpal navicular in veterans, (2) the treatment of such fractures, and (3) the veteran's subsequent life adjustment. There were obvious limitations to such a study because only one forty-to-sixty-minute interview with each veteran was possible and some veterans resented being interviewed. Nonetheless data for statistical comparison were obtained.

The method of study employed consisted of (1) a psychiatric interview and (2) a questionnaire. The interview concerned itself first with the accident, seeking evidence of purposiveness or other psychological factors in the production of the accident and second other evidences of invalidism, neuroticism, or "compensitis" subsequently. A history of other accidents, operations, or illnesses was obtained, as well as a personal and family history. Most of the men interviewed preferred to be superficial in the more personal areas, but five or six gave a revealing interview.

The questionnaire consisted of two parts, the first including questions dealing with present-day symptoms, the second referring to childhood symptoms.

Each veteran's interview was studied and classified according to accident proneness, impulsivity, neuroticism, and general adjustment. The first two categories were selected because they have been repeatedly described as applying to the "fracture personality", while the other two were chosen to give more complete information regarding the veteran's personality for statistical comparison.

The results of this study of thirty-nine veterans revealed that there was no clear-cut "fracture personality". Marked degrees of impulsivity were not particularly characteristic, in contrast to Dunbar's findings[1]. Only 23 per cent. of these had had two or more previous accidents, while in Dunbar's series 72 per cent. of the fracture group did have such a history of previous injuries. At least six men had personality factors which played a definite role either in the production of the fracture or in complicating the clinical picture. In general the personalities in this group were heterogeneous. Accident proneness, impulsivity, and other personality traits were not predominant. Why the findings in this study differ from those of Dunbar is not clear. Various factors may be responsible. For instance, military personnel were screened psychologically at induction; possibly this eliminated those with excessive tendencies toward accident proneness, impulsivity, and neuroticism, as well as the most poorly adjusted individuals. Furthermore, this group was exposed to more risk of bodily injury than would occur in civilian life ordinarily. As a result, increased exposure to injury may have outweighed personality factors.

Finally, this study, being less thorough than Dunbar's, may have failed to reveal personality traits which more extensive study would have brought to light. It was concluded that a psychiatric study would be of little value in a large-scale follow-up study of veterans with this fracture.

SUMMARY AND CONCLUSIONS

As the result of an end-result study of forty-four veterans who had fractures of the carpal navicular, recognized while in Military Service during World War II, the following conclusions seemed warranted:

1. If healing by primary union occurs, there is minimal residual disability which does not interfere with the performance of duty.

2. About 50 per cent. of the ununited fractures were surveyed from the Service for wrist symptoms. If non-union is established before induction, this injury should be disqualifying for full-duty status.

3. The incidence of non-union in Military Service was 22 per cent. The factors tending to produce non-union appeared to be insufficiently prolonged immobilization and delay in instituting treatment. Immobilization must be maintained until there is union as shown by x-ray. This may require more than eight weeks, even in acute fractures promptly diagnosed and treated.

4. The treatment of non-union in this series was unsatisfactory. Of the fourteen men with non-union, nine were treated conservatively without improvement; five were operated upon, union and a satisfactory result being obtained in two.

5. Persistent non-union results in partial absorption, displacement and fragmentation of the fragments, cyst formation in the navicular, and degenerative arthritic changes. Functional impairment was present in every case, but earning power was impaired in only 42 per cent. of the cases.

6. A psychiatric study of these patients revealed the personalities to be heterogeneous with no particular trait outstanding. In only six instances were there clearly discernible psychological factors related to the fracture or the veteran's adjustment following the fracture.

7. The work capacity of these injured wrists, as determined by a specially designed recording ergograph, in cases with primary union showed little or no impairment. Only one of the fourteen wrists with non-union showed a normal work capacity. The ergographic tracing in the uncooperative patient was characteristic and proved to be an aid in detecting lack of cooperation.

NOTE: In the original report, there was a complete bibliography.

1. DUNBAR, FLANDERS: Medical Aspects of Accidents and Mistakes in the Industrial Army and in the Armed Forces. War Med., **4**: 161–175, 1943.

DISCUSSION

THE USE OF IPRONIAZID IN THE TREATMENT OF BONE AND JOINT TUBERCULOSIS

(*Continued from page 588*)

I should like to ask Dr. Bosworth about the suitability of iproniazid for local treatment, and further I would like to thank Dr. Bosworth for his pioneering in the use of this drug.

DR. BOSWORTH (closing): While all of the discussors have been very kind, they have brought up many problems. We cannot answer them all. The question of treatment by local injection is one that has arisen. Such treatment has been tried and is unsatisfactory. Inaccurate local and blood-serum levels result. Success in treatment depends upon a very close dosage of this drug in its final contact with living tissue cells and the *Mycobacterium tuberculosis*. In our paper and in this discussion the figures given are those present to the best of our knowledge at this time. One must have the concentration up to 3.5 gammas per milliliter in cultures or in serum to satisfactorily control the tubercular organism. When it begins to drop down toward 2.8 gammas per milliliter, there will be a very definite change in percentage control of the tuberculous infection. So one has to keep toward the higher dosage. Now, what defeats you at keeping toward the higher dosage? It is the fact that this material is found to be, on an average, 50 per cent. higher in the spinal fluid than in the blood serum. If the satisfactory serum level is 3.5 gammas per milliliter, then the spinal-fluid level may be 5.2 gammas per milliliter. With this you have toxicity manifested by central neurotoxic symptoms. Absorption

(*Continued on page 658*)

A SURVEY OF CARPAL AND TARSAL ANOMALIES

BY RONAN O'RAHILLY, M.D., DETROIT, MICHIGAN

From the Department of Anatomy, Wayne University, Detroit

"To collect and codify the facts of Variation is, I submit, the first duty of the naturalist." — (*William Bateson*, Materials for the Study of Variation, 1894).

The congenital anomalies of the human carpus and tarsus are of frequent occurrence and of considerable interest—teratological, embryological, roentgenological, orthopaedic, and medicolegal. A vast although widely scattered literature on the subject has developed, but a comprehensive account does not seem to have been published.

Apart from minor variations in shape, size, or position of the individual bones, there are five chief categories of carpal or tarsal anomalies *: (1) severe anomalies associated with antebrachial (crural) or digital abnormalities, or both; (2) fusions; (3) cases of accessory ossicles, including sesamoids; (4) cases of bipartition; (5) structural alterations associated with deformities such as talipes. The first four of these types will be discussed in this study.

I. EXTENSIVE ANOMALIES †

Extensive carpal or tarsal involvement is found associated with those long-bone deficiencies which have been classified by the present writer as the "paraxial hemimelias" ** and which have been described in detail elsewhere [76]. In brief, radial hemi-

* The Birmingham Revision [5] (1933) of the Basle Nomina Anatomica (1895) is used throughout this paper. The following list gives the names of the carpal and tarsal bones (the original B.N.A. terms are given in parentheses when they differ from the Birmingham Revision): scaphoid (naviculare), lunate, triquetrum, pisiform, trapezium (multangulum majus), trapezoid (multangulum minus), capitate, hamate, talus, calcaneum (calcaneus), navicular, medial (primum), intermediate (secundum), and lateral (tertium) cuneiform bones, cuboid. In regard to the B.N.A., it may be pointed out that the use of the term naviculare in both carpus and tarsus is clearly inadvisable, and that the terms multangulum majus and minus are unnecessarily cumbersome and do not lend themselves to the formation of compounds. It should be remembered that the B.N.A. is officially a Latin nomenclature and that translations of it are arbitrary. The carpal and tarsal names of the Jena Nomina Anatomica (1935) are almost identical with those of the B.N.A. Although human terminology may frequently not be suitable for application to comparative anatomy, the suggestion [51] that a "morphological terminology" should be used is practicable only through adoption of a standardized scheme of homologies; as agreement on such schemes is lacking, the use of such terms in human anatomy would lead to even more confusion than hitherto.

In the carpus the scaphoid, lunate, and triquetrum are generally homologized with the radiale (together with a centrale), intermedium, and ulnare, but other suggestions are not wanting; thus the lunate, triquetrum, and pisiform are homologized with a centrale, the intermedium, and ulnare. No agreement has ever been reached concerning the pisiform. The distal carpals are homologized with carpalia 1 to 5, the hamate representing 4 and 5, and the capitate possibly including a centrale. In the foot, Wood Jones [51] followed the older scheme of homologizing the talus, os trigonum, and calcaneum with the tibiale, intermedium, and fibulare; the navicular with a centrale, and the cuneiforms and cuboid with tarsalia 1 to 5, the cuboid representing 4 and 5. According to more recent speculations, the os tibiale externum is homologized with the tibiale; the talus with the intermedium together with one or two centralia; the calcaneum with the fibulare and a "pisiform" or a "postminimus" and perhaps with a centrale; the navicular with two centralia; the cuneiforms and cuboid with tarsalia 1 to 5, the cuboid representing either 4 (the os vesalianum then perhaps representing 5) alone, or 4 and 5. These speculations are cited for interest and because clinicians are fond of citing them; the writer refrains from any comment on their justification or value.

† Membral teratology is a subject with an ancient heritage. Hexadactylia is mentioned in the Bible [II Samuel (Kings): xxi, 20]. Pliny [Natural History, Book XI, XCIX (par. 244)] referred to a Roman poet and to two daughters of a Roman noble who had hexadactylia. Scipio Africanus is said to have had hereditary hexadactylia [60], but this requires verification. St. Mark had some form of brachydactylia [88]. A subject with symphalangia described by Drinkwater was descended from John Talbot, First Earl of Shrewsbury, who died in 1453 and who was exhumed in 1874 and was found to show the anomaly.

** Some brief explanations of terms may be helpful. *Teratology*, a term introduced by Isidore St.-Hilaire [68] (1805–1861), is the science of congenital anomalies. Teratogenesis refers to the mode of development of congenital anomalies. *Anomaly*, malformation, defect, deformity are used synonymously for developmental deviations from the "normal". A *monster* is a highly deformed embryo or foetus. *Congenital* means present at (or before) birth. Hereditary anomalies are not necessarily congenital, and congenital anomalies are not necessarily hereditary.

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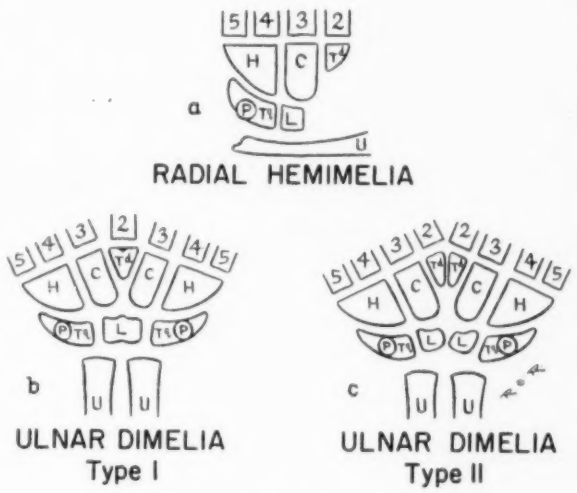


FIG. 1

Examples of extensive carpal anomalies.

a shows typical carpus in radial hemimelia (absence of the radial side of forearm and hand). The radius, scaphoid, trapezium, first metacarpal, and thumb are absent. The ulna (*U*), lunate (*L*), triquetrum (*Tq*), pisiform (*P*), trapezoid (*Td*), capitate (*C*), hamate (*H*), and second to fifth metacarpals and fingers are present. Note the radial deviation of the hand (manus vara).

b: Ulnar dimelia (duplication of ulnar side of limb) Type I, with double radial hemimelia (neither ulna has a radius), and single index finger. Note that the same bones are absent as in the preceding case, but that the bones present in the preceding case are duplicated here and are in mirror-image formation.

c: Ulnar dimelia, Type II, with double radial hemimelia, as above, and duplication of the index finger.

melia (Fig. 1, *a*) tends to be accompanied in more than 80 per cent. of cases by absence of the scaphoid-trapezial-metacarpal-pollical complex, whereas the lunate, trapezoid, second metacarpal, and index finger are present in more than 85 per cent. In ulnar hemimelia the pisiform and hamate (and frequently the triquetrum and capitate) and some of the ulnar metacarpals are generally absent. In tibial or fibular hemimelia, individual tarsal and most of the metatarsal bones are more frequently present than absent, but nevertheless deficiencies are common.

In intercalary defects the parts proximal and distal to the affected area are not necessarily involved. Thus in phocomelia the digits may be surprisingly normal, but carpal fusions are common [42,109]; incidentally, tarsal fusions are frequent in both tibial and fibular hemimelia. Intercalary radial hemimelia is a peculiar condition in which an intercalary defect occurs on the radial side of the wrist. Generally there is a radiostyloid deficiency accompanied by underdevelopment or failure of the scaphoid-trapezial-metacarpal complex; in some cases there is a "floating thumb", that is, a thumb attached to the hand by soft tissues only. Two rare cases of carpal aplasia with antebrachial and metacarpal hypoplasia have been described recently [6].

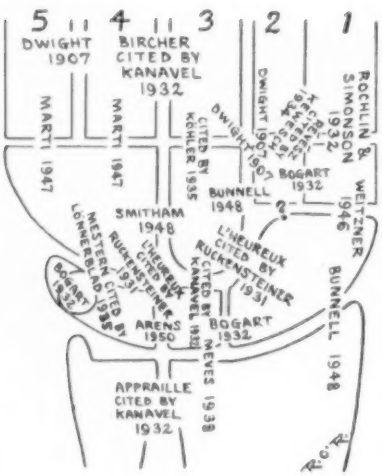
Extensive carpal or tarsal anomalies may also be found in such polymelic conditions as double foetus, symmelia, and partial limb duplications. In ulnar dimelia (Fig. 1, *b* and *c*), for example, there is generally mirror-image duplication and an accompanying double radial hemimelia, that is, neither ulna has a radius. Details of these and similar rare conditions, as well as a discussion of the teratogenesis, have been recorded elsewhere by the present writer [76].

II. FUSIONS

By fusion is here understood the coherence of normally adjacent structures. The term fusion is retained, despite a confusing wealth of suggested alternatives, until more is

(*Continued from page 626*)

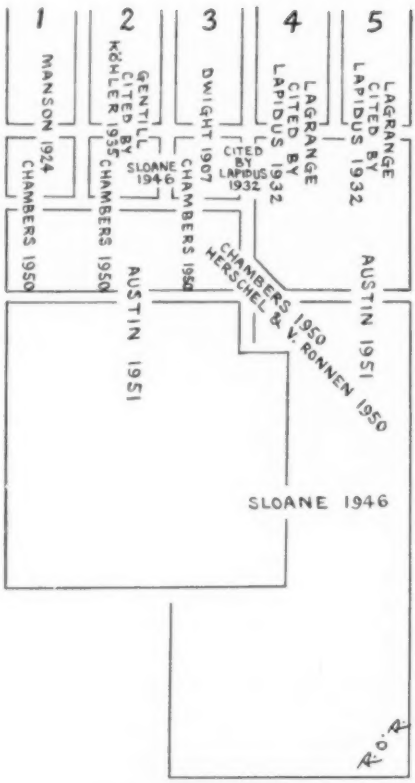
In *hemimelia* the distal portion of a limb is absent. When only one side of the distal part is absent ("paraxial hemimelia") the hemimelia is named (radial, ulnar, tibial, fibular) from the missing portion. In intercalary radial hemimelia, only the middle, as opposed to proximal and distal, part of the radial side of the distal portion of the limb is deficient. *Phocomelia* is an intercalary condition in which, although the hands or feet are present, there is little evidence of the proximal parts of the limb. In *dimelia* (polymelia) a limb or the major part of a limb is duplicated. When only one side of the distal portion is doubled the dimelia is named (for instance, ulnar) from the duplicated part. In *symmelia* the lower limbs appear fused.



CARPAL FUSIONS

FIG. 2

Fig. 2: Scheme of right carpus, anterior aspect, showing some recent cases of carpal coherence. The name of the author reporting the case and the date of publication are placed across the fused bones in each case.



TARSAL FUSIONS

FIG. 3

Fig. 3: Scheme of the right tarsus, superior aspect, showing some recent cases of tarsal coherence. The name of the author and date of publication are placed across the fused bones in each case.

known concerning how such unions or non-separations arise.§

Fusions have been found in almost every possible combination in the carpal * and metacarpal region (Fig. 2), and in the corresponding portion of the foot (Fig. 3). They occur in other regions also, in vertebrae ("cervical sacrum", for example, as in the Klippel-Feil syndrome), or in the sacro-iliac joint (Naegele and Robert pelves). Carpal and tarsal fusions are associated sometimes with hereditary symphalangia [2,8,31,103,112,123].

Hereditary mass carpal and tarsal fusions have been recorded [53].

A number of reviews and collective reports of carpal fusions have been published [9,59,67,70,109]. The most common carpal fusion is the lunate-triquetral (os lunatotriquetrum),

§ According to a theory which seems to stretch the rule of restoration of norms too far, in the event of absence of one element, a contiguous structure forms both parts. The present writer inclines to the view that, in carpal or tarsal fusions, there is probably an absence of joint cavitation in the embryo [26,58] and a chondrification of the joint "interzone". So-called normal constant embryonic articular fusions in the human [124] are probably artefacts [52]. Embryonic tarsal fusions [118] have not been described adequately. Probable anomalous fusions have been found in isolated instances, as of the capitate and third metacarpal in the newborn [110], calcaneonavicular fusion in a twenty-five-millimeter embryo and talocalcaneal in a sixty-millimeter embryo [58], interphalangeal fusion at ten months [99], and, between the dorsal parts of the trapezoid and third metacarpal in a 170-millimeter foetus by the present writer. The normal fusions which occur constantly between such structures as the embryonic human scaphoid and centrale, or between the scaphoid and lunate in many mammals, may provide a guide to the embryology of anomalous fusions. The middle and distal phalanges of the fifth toe, which are often fused in the adult, have been found fused in the foetus [115]. The possibility of postnatal pathological fusions should be remembered; in one case a woman who had tuberculosis of the left talonavicular and cuneonavicular joints at the age of eleven years showed a perfect talonavicular fusion at the age of twenty-two [57]. The production of fusions in experimental embryology is outside the scope of this paper.

* According to one writer [9] "the trapezoid and navicular have been found fused once but no example of this anomaly was found [in this series]." A case of coherence between the scaphoid and trapezium [119] has been quoted incorrectly [27] as an example of scaphoid-trapezoid fusion.

first observed by Soemmering [23]. It was seen once in 743 wrists (0.13 per cent.) by the present writer (in the same series there were two instances of capitate-hamate fusion, and two of trapezium-trapezoid fusion, that is, a total of five cases of fusion, 0.7 per cent.). Other workers have found three cases of lunatotriquetral fusion in about 2,100 wrists, 0.14 per cent.[53], and four cases in 5,000 carpal roentgenograms, 0.08 per cent.[1] It has a higher incidence in negroid peoples, however (forty cases in 680 West Africans or 6 per cent.[102]); and a number of writers have remarked on racial variations. It may be bilateral or unilateral, occurring on the right or left side, and is commoner in males. There is generally a distal groove between the bones in cases of lunatotriquetral fusion, but cases without a groove (a description of dissected specimens has appeared [23]) or with a proximal groove occur also. The frequent existence of this sulcus at the site of the epitriquetrum suggests that this accessory element probably plays no part in the formation of this condition.**

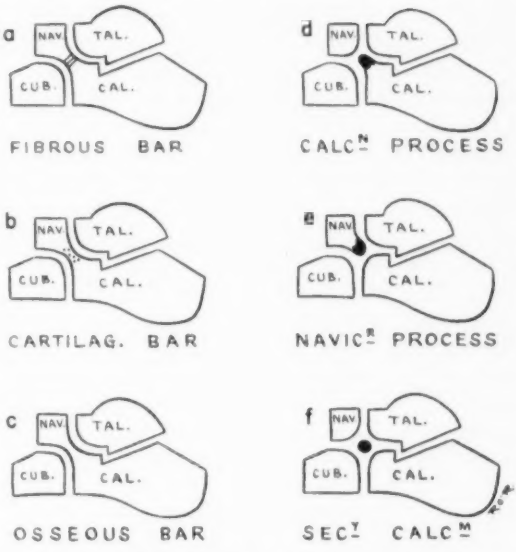


FIG. 4

Variations at the site of the calcaneonavicular bar (modified from Seddon). On the left side the calcaneum and navicular are represented as united respectively by *a*, fibrous; *b*, cartilaginous; and *c*, bony tissue. On the right side are shown *d*, a prominent process on the calcaneum; *e*, a prominent process on the navicular; and *f*, a separate calcaneonavicular ossicle (calcaneum secundarium).

In a similar way a talocalcaneal bridge or a free ossicle (os sustentaculi) may occur between the talus and the sustentaculum tali of the calcaneum.

Certain types of tarsal fusion have, since the work of Slomann[105,106], been recognized to be of considerable clinical importance. The condition commonly called "peroneal spastic flat-foot" is generally due to a talocalcaneal or a calcaneonavicular fusion, infrequently to a tarsal arthritis[18,37,41,122]. A talocalcaneal bridge occurs between the body of the talus and the posterior end of the sustentaculum tali, at the site of the os sustentaculi. A calcaneonavicular bar (probably first discussed by Cruveilhier in the 1830's[58]) occurs between the anterior end of the calcaneum and the lateral end of the navicular. The bar may be fibrous, cartilaginous, or osseous (Fig. 4, *a*, *b*, and *c*); alternatively, an exaggerated projection may be found on either the calcaneum or the navicular (Fig. 4, *d* and *e*), or an accessory ossicle (calcaneum secundarium) (Fig. 4, *f*) may be found at the site[101]. Special oblique projections of the foot are required for an adequate roentgenographic demonstration of these conditions. Arthritic lipping at the superolateral edge of the head of the talus (presumed to be secondary to limitation of movement at the talocalcaneonavicular joint) is a roentgenographic indication to examine oblique views of the foot for tarsal anomalies.

III. ACCESSORIA

Although Vesalius [91] in 1543 had illustrated in his *Fabrica* the inconstant bones since called after him, little attention had been paid to the accessory ossicles until the detailed

** A number of authors [17,18,31,37,43,61,108,118] since Pfitzner have suggested that an accessory element may play a determining role in the development of fusions. Fusions between the third metacarpal and trapezoid "may occur through the styloid or otherwise and may be either bony or cartilaginous" [37].

studies of Gruber, Thilenius, Pfitzner, Dwight, and Grumbach were made in the last hundred years. Pfitzner's monumental work was marred, however, by his dominant theme of endeavoring to consider each inconstant bone as a primitive ossicle of evolutionary significance [20,51]; remnants of such outmoded concepts and others of a similar nature can be found in the majority of present-day reports of anomalies. * A review of the literature soon leads to the conviction that in the present state of knowledge the accessory ossicles, like the carpalia and tarsalia themselves, are better called by names connected with their position or shape (however fanciful) than by "morphological" terms overloaded with speculative evolutionary overtones. To refer to an ossicle as the "epitriquetrum", for example, is a relatively innocuous procedure, whereas to call the same ossicle by the highly "scientific" sounding name "centrale 4" immediately involves the writer in a carpal theory, and a very unsubstantiated theory. It is to be stressed that the terms selected here for the accessoria are as far as possible intended to be positional in significance and must not be veiled with far-reaching implications. The accessoria are "primarily an ontogenetic problem" [92].† The accessory ossicles, "although they illustrate no phylogenetic principles . . . do make evident the ontogenetic truth that prominent outgrowths of individual bones often tend to hav a separate centre of development and, as Dwight says, they show 'the readiness of the elements of the tarsus to change their shape according to the circumstances'" [51].

It is well known, however, that in the case of a very few of the accessoria a bone in a similar situation is found as a more constant element in certain comparable animals. The significance of these findings is nevertheless very obscure and much further comparative work, particularly embryological studies, remains to be accomplished. A centrale, for instance, is found as a separate bone in the carpus of the lower catarrhines; in the gibbon and orang it fuses with the scaphoid in old age, and in the chimpanzee it fuses at about the time of birth [98]. In the human embryo a mesenchymal condensation appears at the site of the centrale and fuses with the scaphoid condensation. The positional similarity and fusion pattern suggest that there is in some sense a correspondence between these centralia of the primates which is technically referred to as "homology". Homology in its original and only satisfactory meaning (an excellent discussion of this subject has been published [11]) of essential structural similarity can thus be applied correctly in teratology; for example, well developed fingers in a sacrococcygeal teratoma [74] or a digit above and behind the calcaneum [87] are homologous with normal digits.

* "The majority of authors agree that these bones are to be considered as rudimentary elements inherited from the lower animals." [15] Apparently then the majority of authors are still unaware of the hazards of basing phylogenetic speculations on teratological observations. "Such loose speculations can only serve to bring morbid anatomy into discredit" [74]. To refer to a human accessory ossicle as "the atavistic first ray", or "a vestigial pisiform digit", or "the remainder of the seventh ray", for example, is surely not warranted in the present inadequate state of available knowledge; the tibiale externum, paracuneiforme, cuneometatarsale I tibiale, and cuneometatarsale I plantare have all been claimed to be a "prehallux"! Furthermore, the genetic fallacy is almost invariably invoked regarding supposed "reversions", as indicated by Dwight [24]: "To point out the animal in which a certain anomaly is normal has been too often offered as an explanation". The genetic fallacy is also frequent in discussion on heredity: "the use made of the word 'heredity' often shows that our contemporaries are as ready as were any of their forefathers to rest content with mere words and phrases" [71]. Whereas "it must be evident that to ascribe any condition normal or abnormal to a gene or a mutation is the beginning, not the end of a problem" [22]. Other instances of careless or meaningless wording could be multiplied indefinitely. A number of writers imagine that "evolution" is a cause, for example. Sesamoids are caused by "phylogeny",[7] and the presence and development of the patella is due to "phylogeny and phylogeny alone" [13], whatever that may mean! A recent book on the accessoria [118] is packed with similar absurdities. Writers should acquaint themselves with recent views on so-called recapitulation [9,73]. On such topics we sympathize with Mark Twain: "There is something fascinating about science. One gets such wholesale returns of conjecture out of such a trifling investment of fact."

† It is not proposed to discuss here the embryology of the accessory elements. A number of the carpal accessoria have been found in serial sections of early human embryos by the present writer (thus confirming the work of Thilenius). The significance of these embryonic condensations is "very obscure" [49]. It has been held (one writer [118] does not agree) that the accessoria (including sesamoids) are more frequent in embryonic life; only the marginal digital sesamoids are those commonly encountered postnatally. The possibility of a postnatal or pathological origin [118] or both in some instances has to be kept in mind, such as heterotopic ossification in synovial tags [92]. "There is reason to emphasize . . . that one and the same type of accessory bone need not have the same genesis in different individuals" [116].

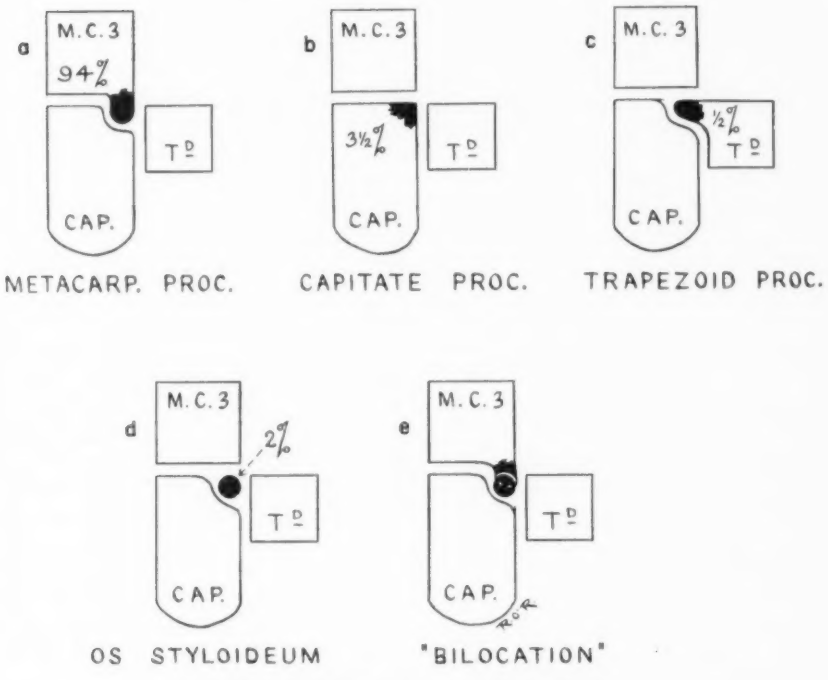


FIG. 5

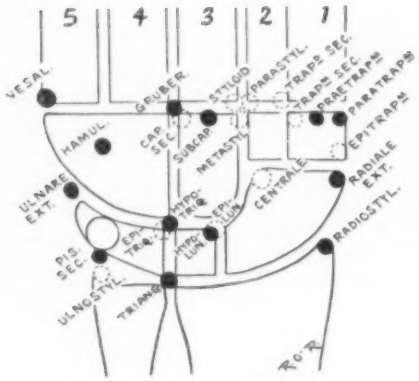
Variations of the processus styloideus of the third metacarpal bone. The third metacarpal (M.C.3) styloid process (black) is an integral part of the metacarpal in 94 per cent. of cases (*a*). It may be found, however, as (*b*) a portion of the capitate in 3.5 per cent., as (*c*) a portion of the trapezoid (*Td*) in 0.5 per cent., or (*d*) as a free ossicle (os styloideum) in 2 per cent. In some cases a separate ossicle may occur together with a distinct process (on the third metacarpal, for example, as in *e*) in the one hand.

The accessory ossicles of the foot have been defined in the following terms [115]:

"Accessory bones are all inconstant, independent, well-defined bones—in an otherwise normally developed foot—the existence of which is not due to a recent minor fracture or other definitely pathological condition, no matter whether these bones bear no, or a less or more intimate relationship to the constant bones, or entirely replace them because of a division of the latter into several segments."

Certain of the accessory tarsal ossicles are commonly referred to as sesamoids, but the difficulty arises of deciding what is a "sesamoid" bone. A sesamoid was defined by Scholder in a passage which may be translated as follows: A skeletal (fibrous, cartilaginous, or osseous) part, with or without an articular surface, developed in the thickness of a tendon, at its site of reflexion, in the neighborhood of a joint, not being a part of the primordial skeleton, but representing a recent functional acquisition, which sometimes has not yet become a constant element, of absolutely determined form.

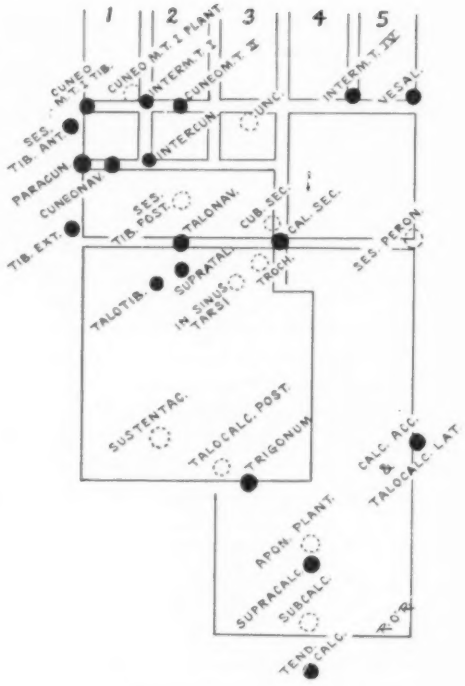
There appears to be some evidence, however, that some of the bones commonly called sesamoids are developed (perhaps ontogenetically) in joint capsules and obtain a secondary attachment to tendon [79]. Pfitzner's definition [13] of a sesamoid as a bone which cannot be classified into any other appropriate category but which belongs to an anatomical lumber room has much to recommend it! Accessory bones will be taken here to include sesamoids; bipartite bones will be dealt with in a subsequent section.



CARPAL ACCESSORIA

FIG. 6

Fig. 6: Scheme of accessory carpal ossicles. Palmar aspect of the right hand; the more dorsally situated ossicles are shown in broken outline. From this diagram the names of the ossicles in a given region of the hand can be determined; the descriptions of these ossicles provided in the text may then be used as a guide in the differential diagnosis of a given case.



TARSAL ACCESSORIA

FIG. 7

Fig. 7: Scheme of accessory tarsal ossicles, dorsal aspect of the right foot; the more plantar-situated ossicles are shown in broken outline. From this diagram the names of the ossicles in a given region of the foot can be determined; the descriptions of these ossicles provided in the text may be used as a guide in the differential diagnosis of a given case.

A peculiar characteristic of at least some accessory ossicles deserves wider recognition; this was described by Dwight as the occurrence of an ossicle in two places at one time. Thus the os styloideum, for example, is found as a free element in the absence of the styloid process of the third metacarpal; but it may, in another case, be found as a free element in association with a well developed metacarpal styloid process (Fig. 5). Similarly it may occur in the same hand as a process on both the metacarpal and the capitate. Hence the os styloideum occurs either *as* the styloid process or merely *at* the styloid process. A number of Dwight's examples of what we shall here term "bilocation" have been seen by the present writer in the Warren Museum, Harvard University Medical School.

It should be stressed also that the accessory ossicles may occur either bilaterally or unilaterally (in the foot they may occur more often unilaterally [102]), and can undergo fracture and pathological changes.

The writer has had the opportunity of examining for congenital anomalies 743 routine roentgenograms of the adult carpus made at the Detroit Memorial Hospital (nine others were discarded as grossly pathological, and one other film showed a case of cleft hand). The possible instances of accessory ossicles totaled forty-five (6 per cent.). As quite a number of these cases were very likely traumatic in origin, the incidence of accessory carpal ossicles is considerably smaller, and not more than twelve cases (1.6 per cent.) were regarded as above suspicion; similarly another worker found 0.4 per cent. in 1,452 subjects [9]. This is in striking contrast with accessory tarsal ossicles of which incidences varying from 25 per cent. to 75 per cent. have been reported.

A number of reviews and collective reports of the accessory carpal ossicles have been published in English [7,9,27,55,81,121]. More than twenty types have been differentiated

(Fig. 6). An unusual hereditary series of carpometacarpal ossicles has been traced through six generations[75]. In the following notes an attempt has been made toward standardizing the terminology of the accessoria in agreement with the nomenclature for carpal and tarsal bones of the Basle Nomina Anatomica, the Birmingham Revision, and the Jena Nomina Anatomica (other terms, considered less desirable, are placed in parentheses). The two eponymous ossicles (Gruber, Vesalius) have not yet been renamed. The ossicles will be arranged alphabetically, since the writer does not favor the groupings of either Pfitzner or Thilenius. The insertion of an ossicle in this list should not be taken as implying the belief of the present writer in the congenital and non-traumatic nature of any given element.*

Ossa carpalia accessoria et sesamoidea

Os capitatum secundarium: at the dorsal distal ulnar angle of the capitate, between the capitate, hamate, and the third and fourth metacarpals.

Os centrale (dorsale): a dorsal ossicle between the scaphoid, capitate, and trapezoid (the existence of a palmar centrale is doubtful). Almost constant in the human embryo of seventeen to forty-nine millimeters, it generally fuses with the dorsal distal ulnar side of the scaphoid. It does not constitute all of the scaphoid distal to the waist, as has been claimed [50], and a separate centrale is therefore a condition distinct from bipartite scaphoid. It has been suggested that in some few cases the centrale may fuse with the capitate or trapezoid [27], or that it may degenerate or form an area of fibrous or cartilaginous tissue. A well developed centrale may form a projection on either the scaphoid [65] or the capitate [111]. A notch is frequently seen roentgenographically on the lateral side of the capitate; it has been called the canalis dorsopalmaris carpi (lateral intercarpal space [77]) and is believed to be the site of a centrale [120], although it has been attributed also to incomplete fusion of two capitate centers [111].

Os epilunatum: at the dorsal distal radial angle of the lunate, between the scaphoid, lunate, and capitate. It is said to fuse with the scaphoid occasionally [27], and it is claimed that there is usually a notch on the normal scaphoid indicating its site [49].

Os epitrapezium: on the dorsal surface of the trapezium next to the scaphoid.

Os epitrapezoideum (os trapezoideum dorsale): Pfitzner used this term for the greater part of the dorsum of the trapezoid. (See also under bipartition.)

Os epitriquetrum (os epipyramis): at the dorsal distal radial angle of the triquetrum, between the lunate, triquetrum, and hamate ("medial intercarpal space" [77]). Pfitzner does not represent the epitriquetrum as meeting the capitate. (See also hypotriquetrum.)

Os gruberi: a very rare palmar ossicle between the capitate, hamate, and the third and fourth metacarpals.

Os hamulare basale and *os hamuli proprium:* at the hook of the hamate (it may occur associated with a well developed hook [28]). Two ossicles have been illustrated [84] in this region—one at the base of the hook and one belonging to the hook proper.

Os hypolunatum: at the palmar distal radial angle of the lunate, between the scaphoid, lunate, and capitate.

Os hypotriquetrum: This term was suggested by the present writer [77] to denote a palmar ossicle in the same interval as the epitriquetrum. Only one definite case [92] seems to have been described.

Os interphalangeale (see under interphalangeale of the foot).

* Ossicles at some sites are of very doubtful "normality", and certain ossicles are so rare as to preclude reaching a conclusion at the present time. It is possible that ossicles may yet be discovered at new sites; there are still a number of places where they have not yet been found, for instance between the scaphoid, trapezium, and trapezoid. Similarly, in the case of the foot, another intercuneiform may yet be found between the navicular, intermediate, and lateral cuneiforms [27].

Os metastyloideum: a dorsal ossicle between the trapezoid, capitate, and third metacarpal styloid process. It may be free or fused with one of its neighbors [27].

Os parastyloideum: a dorsal ossicle between the trapezoid, second metacarpal, and third metacarpal styloid process.

Os paratrapezium: at the distal radial angle of the trapezium next to the lateral side of the first metacarpal base. An unusual case has been published recently [90].

Os pisiforme secundarium (os ulnare antebrachii): proximal to the pisiform, in the flexor carpi ulnaris tendon. This is believed to articulate with the triquetrum. Note that the pisiform may have two ossific centers [27,55].

Os praetrapezium: a palmar ossicle at the distal end of the crest of the trapezium. An unusual case has been published recently [90].

Os radiale externum: at the tubercle of the scaphoid, next to the trapezium. A bilateral scaphotrapezial ossicle, in a boy aged fifteen, which fused with the scaphoid one year later has been described [34]. The "externum" of the radiale externum and ulnare externum presumably means lateral and medial, respectively.

Os radiostyloideum: This name may be used for an ossicle of very doubtful origin [38,62].

Os scaphoideum bipartitum (see under bipartition).

Os sesamoideum interphalangeale and *metacarpophalangeale:* These ossicles are outside the scope of this paper.

Os styloideum: a dorsal ossicle (Fig. 5) between the trapezoid, capitate, and the second and third metacarpals. Apparently its recognition, by Saltzmann, dates back to 1725 [34]. It may occur associated with a well developed third metacarpal styloid process (as can be seen in some of Dwight's specimens at Harvard University). The third metacarpal styloid process was found to be a part of the third metacarpal in 94 per cent. of one series, but may be a part of the capitate (3.5 per cent.), or trapezoid (0.5 per cent.), or it may be a free ossicle (2 per cent.) [1,7]; the process on the third metacarpal commonly does not articulate with the trapezoid but may do so occasionally.

Os subcapitatum: a palmar ossicle between the trapezoid, capitate, hamate, and third metacarpal. This was found by Dwight [25].

Os trapezium secundarium: at the distal ulnar angle of the trapezium, between the trapezium, trapezoid, and the first and second metacarpals.

Os trapezoideum secundarium: a dorsal ossicle between the trapezium, trapezoid, and second metacarpal; regarded as part of the second metacarpal base.

Os triangulare (os intermedium antebrachii, os triquetrum secundarium): between the distal end of the radius, ulnar styloid process, lunate, and triquetrum. It presents a variable and complicated relationship to the articular disc [40,47]. This ossicle may be very difficult to distinguish from a fractured ulnar styloid process, and some cases to which the term triangulare is applied are probably examples of an ulnostyloid. One author [81] acknowledged it only when the ulnar styloid was not deformed; he attributed a long ulnar styloid to fusion with the triangulare. According to Dwight [27] "it may wander towards and beyond the tip of the [ulnar] styloid" and be confused with a secondary pisiform. The triangulare is common in the human embryo; it is said to "disappear" or unite with the ulnar styloid process or become a part of the articular disc.

Os ulnare externum: a term of questionable merit given to an ossicle between the triquetrum, hamate, and pisiform [40], or the triquetrum, hamate, and tubercle of the fifth metacarpal [27]. In a recent case [83] it occurred on the medial aspect of the triquetrum.

Os ulnostyloideum: A separate ulnar styloid process is difficult to distinguish from a fracture, but an accessory ossific center for the ulnar styloid occurs occasionally [55]. It is said that the ulnostyloid includes the triangulare [55].

Os vesalianum (os vesalii) *manus:* between the hamate and the fifth metacarpal, at the ulnar side of the metacarpal tubercle. It may occur in association with a well developed tubercle [25]; one writer [40] claims that it is an atypical hamate ossification, but

his case would probably be called ulnare externum by many workers. Vesalius apparently regarded it as a normal sesamoid [114,*].

Considerably more study has been given to the accessory tarsal ossicles, about thirty of which have been differentiated (Fig. 7). A number of reviews or collective reports have been published in English [4,7,15,27,32,44,45,51,54,55,81,102,118,121]. A discussion of the clinical symptomatology of the tarsal accessoria may be found in Marti.

Ossa tarsalia accessoria et sesamoidea

Calcaneum accessorium: at the peroneal tubercle (processus trochlearis, Basle Nomina Anatomica) of the calcaneum, below the lateral malleolus. An ossicle (referred to as os talocalcaneus) on the lateral aspect of the talus and calcaneum, deep to the peronaei, has been described in a child [43]—os talocalcaneare laterale.

Calcaneum bipartitum (see under bipartition).

Calcaneum secundarium: dorsally, at the anterior and medial edge of the calcaneum, between the talus, calcaneum, navicular, and cuboid (Fig. 4), at the site of the calcaneonavicular bar [37,101], and where an occasional articulation is encountered [56]. It may occur in association with a well developed process on the calcaneum [65]. It has been maintained [66] that the secondary calcaneum may be found in increasingly plantarward situations, and may become indistinguishable from the secondary cuboid. The secondary calcaneum is said to have been found in a mummy from Thebes [45]. The term "secondary calcaneum" has also been used for the front of the sustentaculum tali.

Os aponeurosis plantaris: in the plantar aponeurosis near its origin from the medial tubercle of the calcaneum. Calcaneal spurs are common near the tubercle.

Os cuboideum secundarium: a plantar ossicle between the talus, calcaneum, navicular, and cuboid. It is said to be fused more frequently with the navicular than with the cuboid [27]. There is, however, some doubt whether it has yet been seen completely free [51].

Os cuneiforme mediale bipartitum (see under bipartition). One writer [7], however, refers to "an extra bony piece found in the plantar surface of the [medial] cuneiform" as "division of first cuneiform".

Os cuneometatarsale I plantare (pars peronaea metatarsalis I): at the plantar proximal lateral corner of the first metatarsal base (impression for peronaeus longus).

Os cuneometatarsale I tibiale: medially, near the first cuneometatarsal joint.

Os cuneometatarsale II dorsale: dorsally, near the second cuneometatarsal joint.

Os cuneonaviculare (naviculocuneiforme) *I dorsale* (os infranaviculare, os paracuneiforme I): dorsally, near the medial part of the cuneonavicular joint.

Os in sinus tarsi: in the sinus tarsi.

Os intercuneiforme: dorsally, in the angle between the navicular and medial and intermediate cuneiforms; apparently it is a part of the intermediate cuneiform, on which bone there is often an "intercuneiform fossa" [81].

Os intermetatarsale I (os intermetatarseum): at the dorsal distal lateral corner of the medial cuneiform, between the first and second metatarsals. It is usually fused with one of its three neighbors, but it may be free. It has been suggested that it is a form of polydactylia (Compare a case of lateral cuneiform with three metatarsals in a hexadactyl foot [4]; and a case of bony spicule from the medial cuneiform, medial to the first metatarsal [24]). Others regard it as an ossification in the tendon of the first dorsal interosseous muscle, and it may appear as a metatarsal spur. Apparently there are different types [93]. A large specimen has been recorded recently [35].

Os intermetatarsale IV: in the fourth intermetatarsal interval. A case suggestive of polydactylia has been described [20].

* If the attitude of Vesalius toward variability is frequently influenced by "a Galenic brand of teleology" [113], the subsequent use of the word "teleology" alone by these authors in reference to this "brand" is surely unjustifiable.

Os interphalangeale: laterally, in the interphalangeal joint of the hallux. An interphalangeal ossicle in the thumb has been interpreted as a stage in pollical triphalangia [72].

Os naviculare bipartitum (see under bipartition).

Os paracuneiforme (os praecuneiforme): on the medial side of the cuneonavicular joint.

Os retinaculi: over the area of the bursa of the lateral malleolus.

Os sesamoideum interphalangeale and *os sesamoideum metatarsophalangeale:* These ossicles are outside the scope of this paper.

Os sesamoideum peronaeum (os peronaeale, os cuboideum accessorium): an ossicle occurring frequently in the peronaeus longus tendon, near the tuberosity of the cuboid, on either the lateral or the inferior side of that bone. It may be more closely in relation with the calcaneum [27]. The peronaeum may be present as several segments. Although the ossicle is said to have a frequency of about 8 per cent., there is said to be a peroneal sesamoid or fibrosesamoid in 99 per cent. of individuals, according to Lunghetti [118].

Os sesamoideum tibialis anterioris: in the tibialis anterior tendon opposite the facet on the anterior part of the medial surface of the medial cuneiform. This has been described in a recent report [127].

Os sesamoideum tibialis posterioris: in the tibialis posterior tendon. This ossicle is not likely to be detected roentgenographically [51], in contrast to the tibiale externum.

Os subfibulare: below the tip of the lateral malleolus. It may possibly be a sesamoid in the peronaeus longus tendon [118].

Os subtibiale (talus accessorius, talus secundarius): below the tip of the medial malleolus. It is seen mostly in children, and in many cases appears to be a malleolar epiphysis. The term "subtibiale" has been used also for the os sustentaculi.

Os supratalare (talus secundarius): on the dorsum of the talus between the ankle and talonavicular joints. It may be fused ("trochlear process" of talus) or free.

Os sustentaculi (proprium): at the posterior end of the sustentaculum tali of the calcaneum ("suprasustentacular spine"), or at the site of the talocalcaneal bridge [37]. A talocalcaneal articulation may develop here [16]. An ossicle has also been found at the front of the sustentaculum (see calcaneum secundarium).

Os talocalcaneare laterale (see calcaneum accessorium).

Os talocalcaneare posterius: at the (posterior) talocalcaneal joint.

Os talonaviculare dorsale (os supranaviculare): a dorsal ossicle at the talonavicular joint. Osteo-arthritic outgrowths may occur in this region. The ossicle was known long before Pirie's description of it (perhaps even as early as 1860 [64]); the statement [45] that it had escaped observation is incorrect.

Os talotibiale dorsale: at the front of the ankle joint.

Os tendinis calcanei: in the tendo calcaneus near its attachment to the calcaneum. Calcaneal spurs are common near this tendon. A digit at the back of the tendo calcaneus has been described [87].

Os tibiale externum (os naviculare accessorium or os naviculare secundarium): This was described by Bauhin in 1605 [32]. "Tibiale externum" (the "externum" presumably means medial) is a term of questionable merit for an ossicle near the tibialis posterior tendon, near the tuberosity of the navicular. The ossicle is apparently not the posterior tibial sesamoid [51]. It is said to be usually behind the tuberosity but occasionally medial to it; or it may be fused with it (os naviculare cornutum, scaphoïde débordant). Instances of fusion have been followed roentgenographically; histologically, fibrous or cartilaginous joints have been found between the navicular and the tibiale externum [126]. The ossicle may be in several segments. The tibiale externum may be associated with pain [115]. A roentgenographically undetected cartilaginous tibiale externum may also prove significant clinically. Fracture of the navicular tuberosity is rare. Despite the frequent occurrence of the tibiale externum and the extensive literature pertaining to it, no agreement has

been reached, and the multitude of theories concerning it show clearly the paucity of knowledge regarding the accessoria.

Os trigonum (os intermedium tarsi, talus accessorius, talus secundarius): recognized by Rosenmüller in 1804 [32]. At the posterior tubercle (lateral projection of the processus posterior, Basle Nomina Anatomica) of the talus. Its frequency is given variously as between 2.5 per cent. and 11.4 per cent. It may be fused with or it may articulate with either the talus or the calcaneum. It has to be distinguished from fracture of the posterior tubercle of the talus, the so-called "Shepherd's fracture", which is rare.

Os trochleae: on the lateral side of the plantar calcaneonavicular ("spring") ligament. The term "os trochleae" has been used also in reference to the peroneal tubercle (see under calcaneum accessorium) and for an ossicle or process on the dorsum of the neck of the talus (see under os supratalare).

Os uncinatum (os unci): a plantar ossicle on the lateral cuneiform next to the third metatarsal. It is said that it may appear as a hook-like process on the lateral cuneiform, or that it may be free.

Os vesalianum (os vesalii) *pedis:* This name was given by Pfitzner to a rare ossicle which constitutes the tubercle of the fifth metatarsal. It is to be distinguished from a proximal metatarsal epiphysis, which is smaller, and from a fracture (the "dancing" fracture of Sir Robert Jones). Some have claimed (perhaps with insufficient justification [51]) that the ossicle featured by Vesalius is a peroneal sesamoid or a metatarsal epiphysis; the original illustrations of the hand and foot in the *Fabrica* have been reproduced [91]. The vesalianum pedis has been the subject of much discussion [45,51] and there is still confusion in regard to the differentiation and nomenclature of ossicles at the fifth metatarsal base. A roentgenogram of an atypical variant has been published recently [96].

Subcalcaneum (os subcalcis, os tuberis calcanei): an ossicle near the postero-inferior end of the calcaneum. One case [39], attributed to epiphyseal fragmentation, was labeled "os tuberis calcanei" (Basle Nomina Anatomica). In another case [82] the ossicle was situated more anteriorly, apparently near the origin of the plantar aponeurosis (compare the os aponeurosis plantaris). In a further case [69] the ossicle was intermediate in location.

Supracalcaneum (os accessorium supracalcaneum): This ossicle [95] appears to be related to the posterior third of the superior surface of the calcaneum, between the ankle joint and the tendo calcaneus.

IV. BIPARTITION

The distinction between traumatic and non-traumatic division is frequently a matter of overwhelming difficulty. Although it was once maintained that most scaphoid fractures were developmental in origin, the other extreme of opinion must also be avoided, and the statement that "the os naviculare [manus] bipartitum is a fracture of the navicular which has healed with a pseudarthrosis" [93] is rather brief, not to say dogmatic, for a standard roentgenological textbook of many volumes.

The divided scaphoid (os scaphoideum bipartitum) is the best known of the divided carpals, although claims to congenital bipartition have also been made in regard to others, such as the triquetrum and the trapezoid. Indeed one of the earliest recorded cases (although this was probably non-traumatic) was in the lunate [107], and one writer [111] went so far as to claim that "any [carpal] bone may arise from two or even three centers to cause the formation of bipartite or tripartite bones". Some of the accessoria, particularly the digital sesamoids, may be found in a multipartite condition. In the present writer's series of 743 roentgenograms of the carpus one instance (0.13 per cent.) of bipartite scaphoid was encountered.

The subject of bipartite scaphoid and its literature is too extensive to be discussed in detail here. In summary we may say that, although most cases of divided scaphoid

are traumatic in origin, most workers concede that a few instances are congenital. This is supported by the finding [26,27] of a divided scaphoid at birth, suggesting development from two mesenchymal or cartilaginous centers (there seems to be no good evidence that the scaphoid is ordinarily formed from radial and ulnar elements, but Thilenius and some others have claimed that a bipartite development is usual; similarly, the finding of two ossific centers in the scaphoid seems to be a very rare occurrence). The division is generally across the waist of the bone. Bipartite scaphoid may occur with a free centrale [10], and it has been stated [27] that this is a frequent association.

Roentgenographically, criteria for bipartition which have been suggested are not very illuminating. The surfaces should have smooth, regular edges, a clear joint space, and show no arthritic changes; but congenital bipartite scaphoid may become arthritic. There should be a well formed cortex and cartilage-covered surfaces; but pseudarthroses are often cartilage-covered. The density should be normal and there should be no avascular necrosis; but a congenital bipartite scaphoid may fracture. Both congenital bipartite scaphoid and scaphoid fracture may be either unilateral or bilateral. The importance to be attached to absence of a history of trauma is disputed.

Endocrine factors should always be remembered in bone anomalies. The condition known as hypothyroid epiphyseal dysgenesis is characterized by multiple foci, and such foci have been found in carpals and tarsals [125]; the present writer has seen a bipartite scaphoid in the hands of a cretinous woman aged twenty-nine years. A distinction should be made between calcified foci and multiple ossification centers [93].

It has been claimed that a number of the tarsal bones may occur in a bipartite state, as for example the calcaneum (calcaneum bipartitum) or the navicular (os naviculare bipartitum). The occurrence of more than one ossific center for the navicular is not infrequent, but many cases labeled bipartite navicular (often associated with pain and flatfoot) seem to be instances of tibiale externum. The best known example of a divided tarsal bone is the medial cuneiform (os cuneiforme mediale bipartitum), the observation of which by Morel dates back to 1757 [51]. The bone is found in dorsal and plantar parts which may be detected roentgenographically. The condition has been reviewed [3].

The similarity in development, if any, between bipartite and accessory ossicles has not yet been elucidated adequately. The same uncertainty applies in other regions also, as, for instance, in cases of bipartite parietal and sutural bones [78]. Bipartite lunate in a brother, aged nine, and sister, aged seven, has been described and one of the elements was regarded [29] as an epilunatum (just as some workers have considered bipartite scaphoid as a persistent centrale). But these cases had been diagnosed as "questionable hypothyroidism" (a condition associated with multiple centers) and in another case [85] of bipartite lunate in a child aged ten, fusion occurred a year later. On the other hand, accessory ossicles may fuse also; thus a case has been reported of scaphotrapezial nodule in a patient aged fifteen, which fused with the scaphoid one year later [36].

SUMMARY AND CONCLUSIONS

1. The carpus and tarsus are subject to the same types of anomalous development.

2. Congenital anomalies may or may not be hereditary; they may be bilateral or unilateral; and they may undergo pathological changes.

3. Teratological data are commonly misused for the fabrication of unsubstantiated phylogenetic speculations.

4. Four types of anomalies must be distinguished: (a) extensive abnormalities; (b) fusions; (c) accessoria; (d) bipartitions.

5. Carpal absences are usual in the "paraxial hemimelias". Duplications and absences are found in polymelic conditions (double foetus, symmelia, partial limb duplication).

6. Congenital carpal or tarsal fusions may occur between almost any two elements, and probably arise as an absence of joint cavitation, and chondrification of the embryonic "interzone". Lunatotriquetral fusion is the most frequent type in the hand; its relation to an accessory ossicle seems to be gratuitous. "Peroneal spastic flat-foot" is generally due to talocalcaneal or calcaneonavicular fusion.

7. Many accessory ossicles have been described and a number have been found in the embryo. Postnatal pathological origins in some instances must also be kept in mind, however. It is not practicable at present to distinguish "accessory" from "sesamoid" bones. Many accessory bones exhibit "bilocation", that is, they may occur either *at* or *as* a process on one of the major elements. It is suggested that the terminology of the accessoria be standardized in agreement with current anatomical nomenclature.

8. Although most divisions of bones are traumatic in origin, a few cases seem to be congenital. Bipartite scaphoid probably arises from two mesenchymal or cartilaginous centers, and the division is at the waist. Bipartite medial cuneiform is divided into dorsal and plantar parts. Endocrine factors may be operative in some cases of bipartition, as in hypothyroid epiphyseal dysgenesis, characterized by multiple ossific foci.

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COLLES' FRACTURE

A Study of Two Thousand Cases from the New York State Workmen's Compensation Board *†

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Colles' fracture, a common injury, is usually considered to be rather trivial and is often delegated to the orthopaedic neophyte for treatment. It is the purpose of this paper to survey a large number of such fractures, with the emphasis being placed on final results and their contributory factors.

We have defined Colles' fracture as a complete transverse break of the distal one inch of the radius with dorsal displacement of the distal fragment; non-displaced fractures were not included. A considerable number of fractures showed comminution, impaction, or extension into the radiocarpal joint.

METHODS AND MATERIAL

The Workmen's Compensation Board files of the New York State Department of Labor (New York City District) contain some 1,400,000 cases at any one time, which represent the claims folders for the previous ten years. These are catalogued on International Business Machine cards under a number of keys, permitting rapid tabulation of Colles' fracture cases. The medical section of each case folder contains the treating physician's initial report of injury and therapy, with fuller details in a report made two weeks later; it also contains the progress notes, discharge note, details on Workmen's Compensation Board examinations, x-ray reports, reports of insurance-physician's examinations, and, where pertinent, consultant reports and death reports. There is also the report of the final Workmen's Compensation Board examination with a detailed description of the functional and anatomical findings, and the decision of the Board as to the permanent disability in percentage of loss of function of the hand.

For the years investigated, all case folders, to the number of 5,000, classified under Colles' fracture, fracture of the wrist, and fracture of the radius, were obtained; the latter two classifications contained a large number of Colles' fractures. Then the Colles' fracture charts were tabulated; completeness of data was the sole requirement for inclusion. Because of administrative details, only half of the cases from 1946, 1947, and 1948 were available. All of the cases from 1945 and 1949, whether included in our main tabulations or not, were listed as to the type of fracture. Some further cases were drawn from the 1940 and 1941 files; the war years were largely omitted to avoid prejudice in our correlations, although there was no significant difference between the cases of 1945 (injuries of 1944) and of 1949 (injuries of 1948). Fractures of the carpus in these two years were also counted.

Our tabulation for each case of Colles' fracture consisted of: (1) case number; (2) sex; (3) age; (4) involved limb; (5) Workmen's Compensation Board's final estimation of the percentage of disability (percentage of loss of function of the hand); (6) functional loss (pronation, supination, palmar flexion, dorsiflexion, lateral mobility, and exact defects in digit motion) as none, mild, moderate, marked, or complete; (7) diminution of grip (none, mild, moderate, marked, or complete); (8) nature of fracture (simple or compound,

* Adapted from a report by Bacorn and Kurtzke to the Workmen's Compensation Board. The conclusions herein are those of the authors and do not necessarily represent the opinions or policy of the Workmen's Compensation Board. This paper is published with the permission of Miss Mary Donlan, Chairman of the New York State Workmen's Compensation Board.

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impacted, comminuted, or into the radiocarpal joint); (9) degree of residual deformity (none, enlargement, or mild, moderate, or marked deformity); (10) involvement of the ulnar styloid (with or without union); (11) mechanism of injury; (12) treatment (site, reduction, anaesthesia, duration of immobilization, type of physical therapy if given, and duration); (13) sequelae and complications; and (14) time between injury and the final disability award.

The total number of cases thus studied was over 2,100, but obviously not every factor could be evaluated in each case. There were in addition some 1,100 radiocarpal fractures other than Colles' which were listed as to anatomical type.

DISCUSSION OF DATA

In the two years studied most thoroughly (1945 and 1949), Colles' fracture was found to constitute by far the most frequent individual fracture of the radius. In 1945, there were 650 Colles' fractures out of 1,071 radial fractures; in 1949, 662 Colles' fractures were found in 1,118 radial fractures. This gives a total of 1,312 Colles' fractures out of 2,189 fractures of the radius—an incidence of 60 per cent. (Chart II). The next most frequent class of fractures was that of the radial head (proximal) with an incidence of 14 per cent. (306 cases). Fractures of the shaft of the radius extending from the neck to within one inch of the radiocarpal articulation constituted 6.2 per cent. or 136 of these 2,189 radial fractures. The remaining 19.8 per cent. were fractures other than Colles', although they occurred within one inch of the joint: 132 cases (6 per cent.) were fractures of the radial styloid; 22 (1 per cent.) were Smith's fractures, that is, "reversed Colles' fractures"; and 12.8 per cent. were of a heterogeneous group which included fissure fractures, transverse fractures (whether incomplete or non-displaced), and chip fractures.

It was impossible for us to determine an accurate incidence of Colles' fracture among the general population, since no figures were available on the total number of workers covered by the Workmen's Compensation Law. However, we were able to determine the incidence of Colles' fracture among all Workmen's Compensation Board cases for the years of 1945[3] and 1949[5], in which there were 1,312 cases of Colles' fracture out of 133,764 Workmen's Compensation Board cases in the New York City District—an incidence of 0.98 per cent. The frequency in 1945 was 1.02 per cent.; in 1949 it was 0.95 per cent.

During this study it was also possible to determine the distribution of fractures of the carpus (Chart II). In these same years (1945 and 1949) there were 408 fractures of the carpal bones, or less than one-fifth the number of radial fractures and one-third the number of Colles' fractures. Of these, thirty-one were undifferentiated, but among the remaining 377 carpal fractures, that of the navicular constituted 70.8 per cent. (267 cases). The next most frequent fracture was that of the triangular (14.3 per cent. or fifty-four cases); then came fracture of the lunate (5.6 per cent. or twenty-one cases). The remaining five bones accounted for but 9.3 per cent. There were eight fractures (2.1 per cent.) each of the pisiform, the greater multangular, and the hamate, as well as nine (2.4 per cent.) of the capitate, with but two fractures (0.5 per cent.) of the lesser multangular. Some of these carpal fractures were multiple.

It was interesting to note that Colles' fracture, the mechanism of which demands transmission of the force through the carpus, was accompanied by but ten fractures of the navicular (0.5 per cent.); no other carpal bone was so involved.

In the years 1945 and 1949, 700 fractures, comprising 58 per cent. of a total of 1,206 cases, occurred in males, whereas 42 per cent. (506 cases) were found in females. The ratio in either year was the same as their other, but for our total of 2,115 Colles' fractures the incidence was 56.5 per cent. male to 43.5 per cent. female. The sex ratio of all Workmen's Compensation Board cases for 1945 and 1949 was 84 per cent. male to 16 per cent. female. In 1945 it was 81.2 per cent. male to 18.8 per cent. female; in 1949, 86.7 per cent. male to 13.3 per cent. female. In other words, despite a five-to-one ratio for

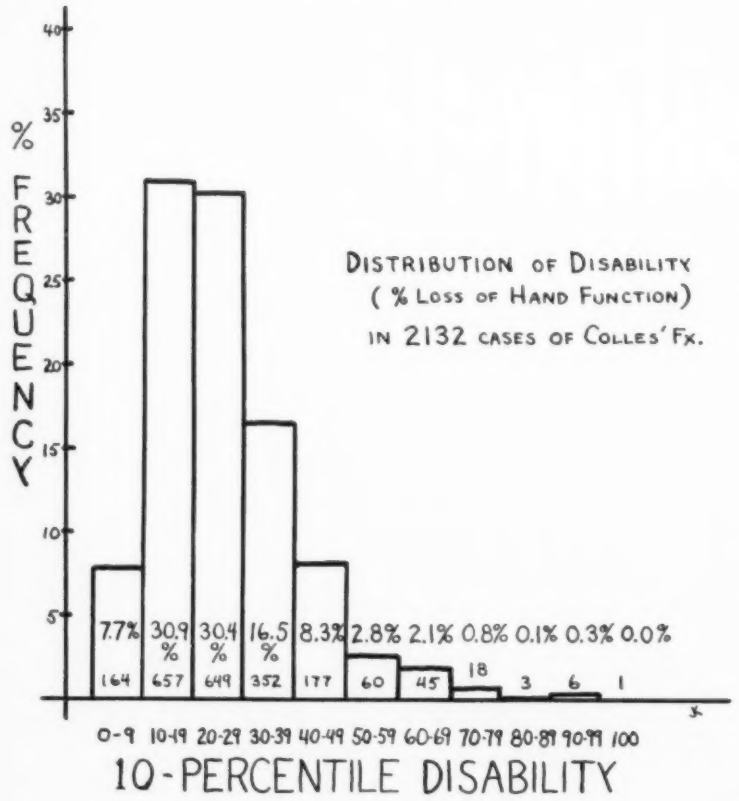

CHART I

NOTE: In this and in the following Charts, the author uses the symbol *Fx* to stand for "fracture."

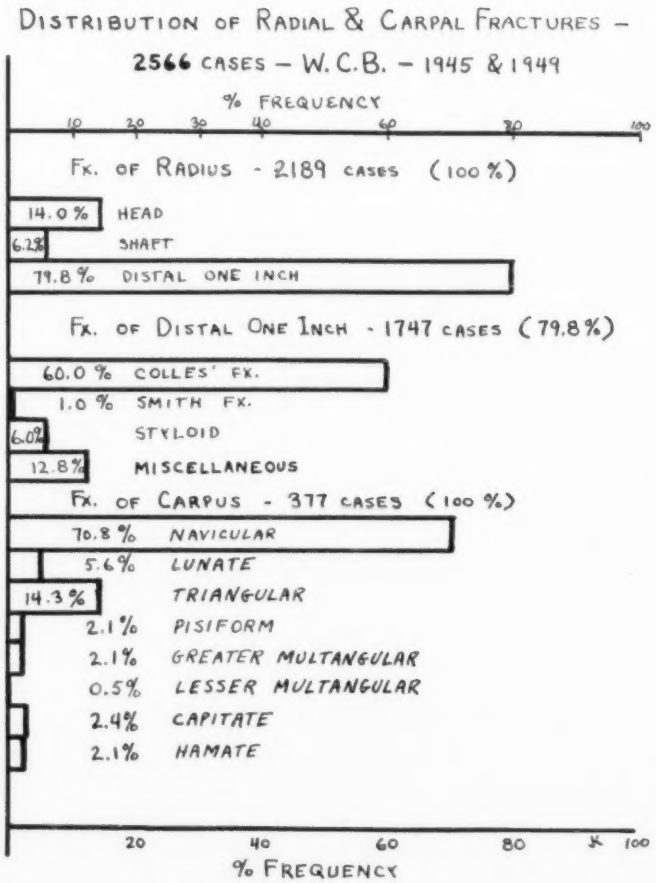
DISTRIBUTION OF RADIAL & CARPAL FRACTURES –
2566 CASES – W.C.B. – 1945 & 1949
% FREQUENCY
10 20 30 40 60 80 100
FX. OF RADIUS - 2189 CASES (100 %)
14.0 % HEAD
6.2% SHAFT
79.8 % DISTAL ONE INCH
FX. OF DISTAL ONE INCH - 1747 CASES (79.8 %)
60.0 % COLLES' FX.
1.0 % SMITH FX.
6.0% STYLOID
12.8% MISCELLANEOUS
FX. OF CARPUS - 377 CASES (100 %)
70.8 % NAVICULAR
5.6% LUNATE
14.3 % TRIANGULAR
2.1 % PISIFORM
2.1% GREATER MULTANGULAR
0.5% LESSER MULTANGULAR
2.4% CAPITATE
2.1% HAMATE
20 40 60 80 100
% FREQUENCY

CHART II

all Workmen's Compensation Board cases, there was almost a one-to-one ratio for Colles' fracture. This we believe was in large part due to the large number of female domestics who had suffered falls resulting in Colles' fracture. Since Colles' fracture is not primarily an occupational hazard, we obtain a sex ratio more closely approximating that of the general population rather than the heavily weighted ratio found in occupational injuries. We can in no other way explain the higher relative incidence in the female.

In 2,103 cases of Colles' fracture, there were found to be 944 fractures of the right radius (44.9 per cent.), and 1,159 (55.1 per cent.) of the left. Included are twenty cases of bilateral Colles' fracture (0.94 per cent.). The higher incidence of fracture in the left wrist does not appear to be of any known significance. There were twenty-seven cases in which the fracture was compound, an incidence of 1.3 per cent.

The mechanism of injury in a Colles' fracture, as is well known, is most frequently the result of a fall on the palm of the outstretched hand. In only 8.4 per cent. (178 cases) was there a different mode of causation—such as being struck by a heavy object, injuries by machines, and chauffeur's fracture. The classical picture of Colles' fracture is a complete transverse break with dorsal displacement of the distal fragment. However, in a considerable proportion of the cases there was comminution, impaction, or extension into the radiocarpal joint. An accurate estimation of the incidence of such forms was impossible, since the reports were usually not sufficiently complete. It was our impression that such forms tended to result in a higher disability.

The primary treatment (reduction and immobilization) took place in a hospital in 55 per cent. (1,179 cases) of the fractures, while a local physician performed this service in the remaining 45 per cent. (953 cases).

Reduction of Colles' fracture was performed in 88.3 per cent (1,348) of the 1,527 fractures in which this factor could be assessed. Of these, 1,252 (81.9 per cent.) were single reductions, fifty-six (3.7 per cent.) required a second attempt, and sixteen (1 per cent.) needed a third manipulation. There were only twenty-four fractures (1.6 per cent.) in which an open reduction was performed. In 179 Colles' fractures (11.7 per cent.), there was no attempt at reduction, although, in our judgment (based upon the x-ray reports, the course of treatment, and the final deformity), eighty of these (5.2 per cent.) were of such a nature that reduction should have been performed. Among these were a number of cases of Colles' fracture in which the patient refused manipulation.

Anaesthesia was used in the reduction of 471 Colles' fractures; in the remainder, this factor was either unknown or anaesthesia was not used, it being impossible to determine which. One hundred and sixty-eight (36 per cent.) were reduced under local infiltration anaesthesia, including but one in which brachial block anaesthesia was used. General anaesthesia (inhalation or intravenous) was used in the reduction of 303 fractures (64 per cent.).

Physical therapy was given in all but 3.4 per cent. of a total of 1,440 cases, with 684 cases in which the type of treatment was not reported. While every conceivable form of therapy from hot soaks to histamine iontophoresis was used, the most popular was diathermy. The frequency of treatment most often noted was three times a week, which is the maximum for which fees are authorized under the Workmen's Compensation Law.[4] The duration of treatment varied from 0.5 to twenty-four months, with a mean or average*

* The mean or average of a class is the sum of the components of a class divided by the number in the class: mean = $M = \overline{X} = \frac{\Sigma X}{N}$

For grouped data (that is, where there are subclasses) mean = $M = \overline{X} = \frac{\Sigma(FX')}{N}$

$M = \overline{X}$ = mean of the X's
N = number in the class
X = member of the class
F = frequency of X'
X' = a subclass (actually, the mid-point of the subclass).

TABLE I

FREQUENCY DISTRIBUTION ACCORDING TO AGE FOR ALL COLLES' FRACTURES AND ALL WORKMEN'S COMPENSATION BOARD CASES OF 1945 AND 1949, COMBINED

Age Group	All Colles' Fractures		All W.C.B. Cases, 1945 and 1949	
	No. of Cases	*Per cent.*	*No. of Cases*	*Per cent.*
II under 20	54	2.6	9,668	4.7
III 20–29	127	6.2	35,312	17.1
IV 30–39	257	12.5	46,395	22.4
V 40–49	563	27.4	50,547	24.4
VI 50–59	683	33.5	42,496	20.5
VII 60–69	325	15.9	19,362	9.4
VIII 70–79	38	1.9	2,815	1.4
IX 80–89	0	0	110	0.1
Total	2,047	100.0	206,705	100.0

of 4.0 months and a median* of 3.5 months. Although no statistical analysis of type or duration of physical therapy in relation to final disability could be made, it is our impression that it did not play any appreciable role in altering the final loss of function. It is felt that the most important effective mode of physical therapy is the active and passive motion done by the patient himself, under proper medical supervision, as frequently and as early as feasible. We have seen rather severe fractures in elderly people treated for short periods result in a below-average disability, which was due in large measure to the patient's willingness to exercise his wrist and fingers. This is also the impression of Knapp and Cassebaum.

Contrary to popular belief, Colles' fracture most frequently results in some residual impairment in motion of the hand and wrist, even under the most favorable circumstances. Only sixty-two (2.9 per cent.) of 2,132 Colles' fractures were judged by the physicians of the Workmen's Compensation Board to have had no permanent disability (loss of function). The average disability in all cases of Colles' fracture regardless of age, adequacy of treatment, or severity of fracture is 24 per cent. loss of function of the hand. The range of disability is from 0 to 100 per cent.; both median and mode** are 20 per cent. loss of function (Chart I). In 94 per cent. of the cases, there was a resultant disability of less than 50 per cent. loss of hand function. This loss, as found by Workmen's Compensation Board examiners, is considered a permanent condition not amenable to further treatment.

In 2,047 cases of Colles' fracture the ages ranged from fourteen to seventy-eight years with an average age of 48.2 years (median and mode each fifty years) (Chart III). This bears out the generally accepted opinion that Colles' fracture is a condition of the older age groups. More concrete evidence of this is afforded by a comparison of the age distribution of Colles' fractures with that of all Workmen's Compensation Board cases for 1945 and 1949, New York City District (Table I), in which 68.6 per cent. of all Workmen's Compensation Board patients are under the age of fifty, whereas 51.4 per cent. of the patients with Colles' fracture are aged fifty or over. A distribution index (defined as the percentage frequency of Colles' fractures per age group over the percentage frequency of all Workmen's Compensation Board cases for the same age-group) shows a sine-curve ratio ranging from 0.35 for the 20–29 age group to 1.68 for the 60–69 age group, whereas

* The median is the value in a class so chosen that the members above and below this value are equal in number when the class is arranged with its members in sequence.

$$\text{median} = \text{Md} = \frac{(N + 1)}{2}$$

For grouped data, median = Md = $\frac{N}{2}$

** The mode of a class is that member which occurs most frequently. M_o = mode.

TABLE II

AGE-DISABILITY CORRELATION IN 2,051 CASES OF COLLES' FRACTURE

(Workmen's Compensation Board Cases, New York City District)

Disability Groups (10 percentiles)	Age Groups in Decades															
	II Under 20		III 20–29		IV 30–39		V 40–49		VI 50–59		VII 60–69		VIII 70–79		Total	
	No.	*Per cent.*	*No.*	*Per cent.*	*No.*	*Per cent.*	*No.*	*Per cent.*	*No.*	*Per cent.*	*No.*	*Per cent.*	*No.*	*Per cent.*	*No.*	*Per cent.*
0–9	24	45.3	23	18.5	36	13.8	36	6.4	30	4.4	11	3.4	0		160	7.8
10–19	21	39.6	63	50.8	100	38.3	214	37.8	167	24.3	62	19.2	6	16.2	633	30.9
20–29	6	11.5	25	20.2	67	25.7	169	29.9	239	34.8	98	30.3	11	29.7	615	30.0
30–39	1	1.9	9	7.3	38	14.6	74	13.1	138	20.1	69	21.3	11	29.7	340	16.6
40–49	0		2	1.6	12	4.6	45	8.0	68	9.9	43	13.3	4	10.8	174	8.5
50–59	1	1.9	1	0.8	5	1.9	13	2.3	22	3.2	13	4.0	2	5.4	57	2.8
60–69	0		1	0.8	3	1.2	8	1.4	15	2.2	17	5.2	1	2.7	45	2.2
70–79	0		0		0		4	0.7	7	1.0	5	1.5	1	2.7	17	0.8
80–89	0		0		0		0		0		3	0.9	0		3	0.1
90–99	0		0		0		2	0.4	1	0.1	2	0.6	1	2.7	6	0.3
100	0		0		0		0		0		1	0.3	0		1	
Total	53	100.0	124	100.0	261	100.1	565	100.0	687	100.0	324	100.0	37	99.9	2,051	100.0

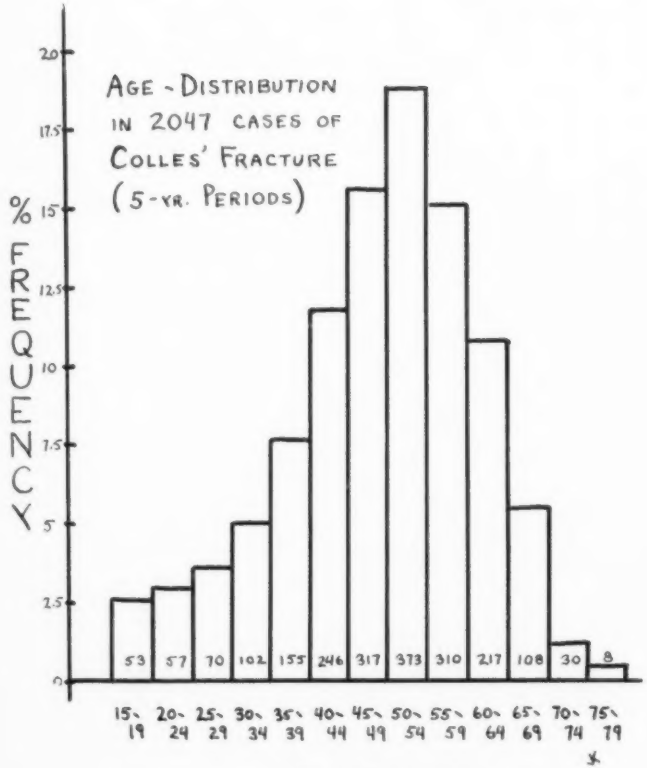

CHART III

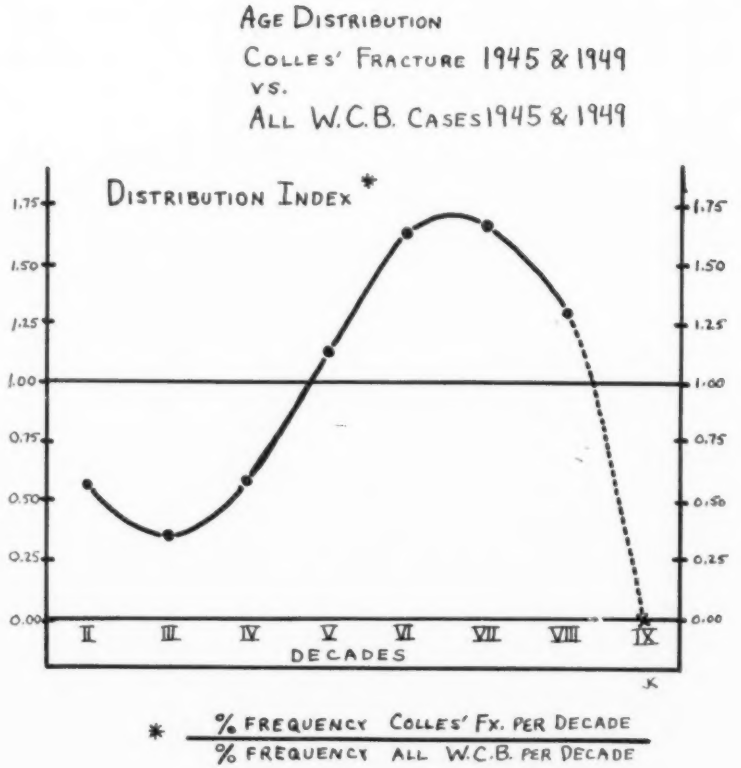

CHART IV

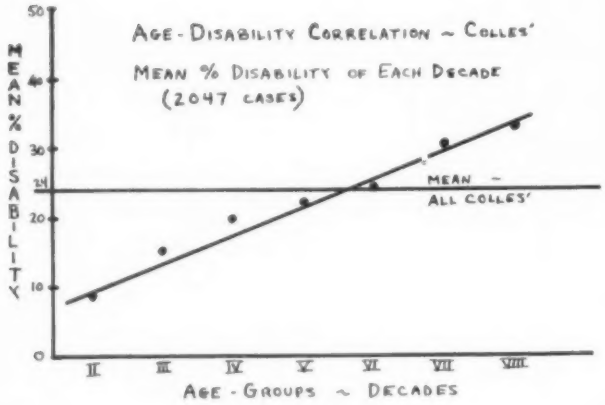

CHART V-A

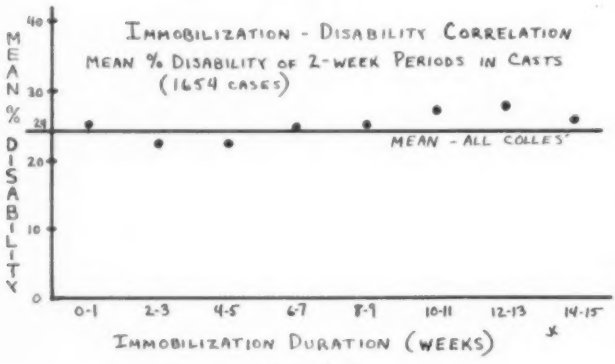
IMMOBILIZATION - DISABILITY CORRELATION
MEAN % DISABILITY OF 2-WEEK PERIODS IN CASTS
(1654 CASES)
MEAN % DISABILITY
MEAN - ALL COLLES'
IMMOBILIZATION DURATION (WEEKS)

CHART V-B

if the age distribution of Colles' fractures were proportional to that of all Workmen's Compensation Board cases, the distribution index would remain constant at 1.00 (Chart IV).

It is commonly felt that not only are Colles' fractures more numerous in the older age groups but they are, in addition, more serious; patients in such groups may expect a higher disability. By a correlation of age and disability, it was determined that the mean percentage loss of function for each successively older age group ranges from 9.4 loss of function for the first group (age less than 20) to 32.3 loss of function for the seventh group (age 70–79), with a straight-line slope approximating an increase in mean percentage disability of 3.7 per decade (Chart V-A; Table II). The mean of each age subgroup has been proved by statistical methods* to be significantly different from the mean of all cases of Colles' fracture, except where the curve of disability-age correlation crosses the value of the mean of all cases. In addition, each age subgroup has been shown to be significantly different** from the means of its contiguous groups — except in the last (70–79) where there is a small number of cases.

* The standard deviation of the mean of the subgroup was compared with the mean of all Colles' fractures. When the two means differ by more than twice the standard deviation of the subgroup, they are statistically different 95 per cent. of the time.

$$\sigma_M = \sqrt{\frac{\sigma_s^2}{n-1}} = \frac{\sigma_s}{\sqrt{n-1}}$$

$$\sigma_S = \sqrt{\frac{\Sigma x^2}{N} - \left(\frac{\Sigma x}{N}\right)^2}$$

For all Colles' fractures

$$\sigma_M = \frac{14.5}{\sqrt{2131}} = \pm 0.314$$

For subgroup a

$$\sigma_{Ma} = \frac{14.5}{\sqrt{a-1}}$$

σ_M = standard deviation mean
σ_S = standard deviation of a sample
Σ = sum of
x = mid-point of subgroup
n = number of samples
a' = number of samples in subgroup a

** T = the critical ratio of the difference between two means. If T is greater than ± 2.0, the two means are significantly different 95 per cent. of the time.

$$Tab = \frac{Ma - Mb}{\sigma_{Dab}}$$

$$\sigma_{Dab} = \sqrt{\sigma^2_{Ma} + \sigma^2_{Mb} - r(\sigma_{Ma})(\sigma_{Mb})}$$

σ_D = standard error difference between sample means
r = coefficient of correlation

The T's found were 4.02, 3.24, 3.32, 2.39, 5.49, and 0.63, respectively.

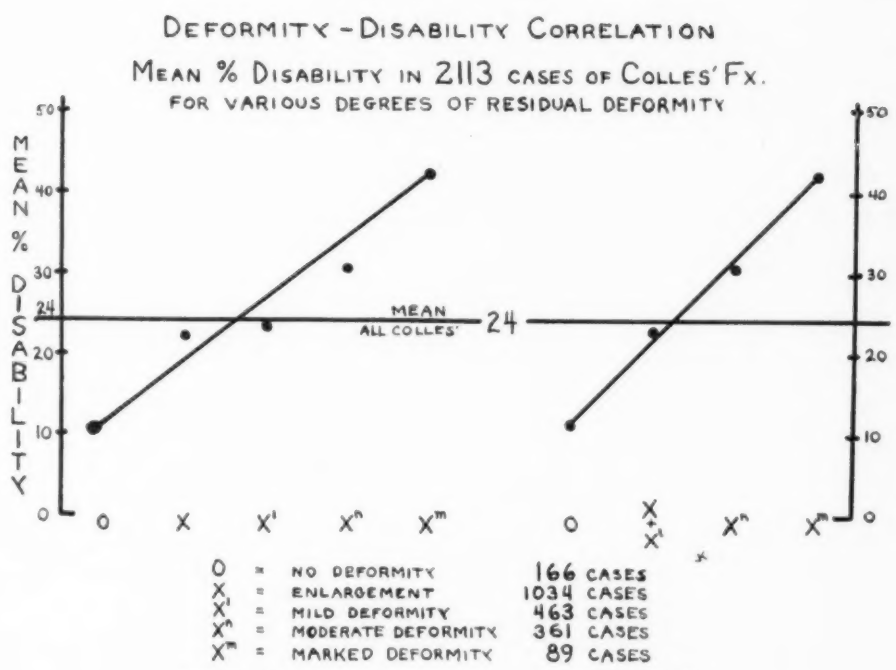

CHART VI-A CHART VI-B

Thus age has been shown to be one important factor in the determination of the final percentage of loss of function in cases of Colles' fracture. Another important element in this regard is the adequacy of reduction and immobilization. These two factors are of course related. In a study such as this, it is impossible to differentiate the two; but one factor incorporates both elements: namely, the degree of residual deformity as adjudged by the Workmen's Compensation Board's medical examiners. Residual deformity has been arbitrarily classified into five categories, the first being the return to the normal contour and size and the second, an enlarged wrist in the absence of deformity. The next three classes are those of true deformity (mild, moderate, and marked) which is most often of a "silver-fork" character. A deformity-disability correlation was set up and the results showed conclusively that disability does increase directly with the degree of deformity in a straight line having a slope of approximately 6 per cent. loss of function per "grade" of deformity (Chart VI-A). The mean percentage disability ranged from 10.6 (no deformity) to 42.1 (marked deformity). A statistical comparison between two adjacent means showed a significant difference in all cases but one, and that was between enlargement only and mild deformity in which the difference was remarkably insignificant, tending to show that they are but two names for the same grade of deformity. In addition, by cumulative distribution* curves, these two "grades", namely, enlargement and mild deformity, are shown to be identical.

Thus we have only four classes of deformity: none, mild, moderate, and marked, with a slope of 10 per cent. disability per grade of deformity. We have found that 86 per cent. of the patients with no residual deformity have a disability of less than 20 per cent., whereas only 3 per cent. of those with marked deformity have this same disability (Chart VI-B; Table III). The significance of this conclusion—that is, that there is a positive

* Cumulative distribution curves plot the cumulative frequency percentage (abscissa) against cumulative percentage disability (ordinate) for each class involved in the correlation — here it is disability.

TABLE III

DEFORMITY-DISABILITY CORRELATION IN 2,113 CASES OF COLLES' FRACTURE

Percentage of Disability (*10 percentiles*)	Types of Residual Disability										Total	
	O No Deformity No Enlargement		X Enlargement Only		X^{i} Slight Deformity		X^{n} Moderate Deformity		X^{m} Marked Deformity			
	No.	*Per cent.*	*No.*	*Percent.*	*No.*	*Per cent.*	*No.*	*Per cent.*	*No.*	*Per cent.*	*No.*	*Per cent.*
0–9	64	38.6	80	7.7	17	3.7	0		0		161	7.6
10–19	78	47.0	369	35.7	179	38.6	43	11.9	3	3.4	672	31.8
20–29	19	11.4	324	31.4	135	29.2	138	38.2	14	15.7	630	29.9	
30–39	3	1.8	146	14.1	72	15.6	96	26.6	25	28.1	342	16.2
40–49	2	1.2	66	6.4	42	9.1	51	14.1	17	19.1	178	8.4
50–59	0		24	2.3	5	1.1	17	4.7	14	15.7	60	2.8
60–69	0		16	1.5	10	2.2	8	2.2	9	10.1	43	2.0
70–79	0		8	0.8	2	0.4	6	1.7	2	2.2	18	0.9
80–89	0		0		1	0.2	0		2	2.2	3	0.1
90–99	0		1	0.1	0		1	0.3	3	3.4	5	0.2
100	0		0		0		1	0.3	0		1	
Total	166	100.0	1,034	100.0	463	100.1	361	100.0	89	99.9	2,113	99.9

correlation between residual deformity and disability—is proved by statistical methods, including the χ^2 test*, using the null hypothesis that there is no correlation between deformity and disability.

One often hears that a cast should be left on a fractured limb for a period just sufficient for adequate callus to form and that immobilization for periods beyond this greatly enhances the probability of an increased final disability, or that immobilization *per se* for some two to three months can cause a permanent loss of function, where none would have resulted had there been no cast present (for example, in sprains treated as fractures). To test this hypothesis, we correlated the duration of immobilization with the percentage of disability in 1,654 cases of Colles' fracture immobilized for periods ranging from zero to sixteen weeks (one case of eighteen weeks) (Chart V-B; Table IV). The average period of immobilization for all of these Colles' fractures was 5.4 weeks, the median being five weeks, the mode four weeks.

By the testing of the means of successive two-week periods of immobilization (and also of four-week periods) against the mean of all cases of Colles' fracture, there was found to be *no* significant difference between the means of the individual subgroups and the mean of all Colles' fractures. We further tested the significance of our entire distribution by

* χ^2 test:

$$\sigma = \sqrt{2\chi^2} - \sqrt{2n - 1}$$

$$\chi^2 = \Sigma\left[\frac{(fo - fT)^2}{fT}\right]$$

$$n = (R - 1)(C - 1)$$

fo = observed frequency
fT = theoretical frequency
Σ = sum of
n = degrees of freedom
R = number of rows
C = number of columns
σ = standard deviation (unit of)

The null hypothesis sets up a theoretical frequency of an ideal distribution (bell) curve. If the hypothesis is correct, σ will be less than 1 in two-thirds of the cases.

$$\sigma = \sqrt{2 \cdot 710.9} - \sqrt{2 \cdot 40 - 1} = 29$$

TABLE IV

IMMOBILIZATION-DISABILITY CORRELATION IN 1,653 CASES OF COLLES' FRACTURE

Percentage of Disability (*10 percentiles*)	Weeks of Immobilization (in periods of 2 weeks)																Total	
	0–1.9		2–3.9		4–5.9		6–7.9		8–9.9		10–11.9		12–13.9		14–15.9			
	No.	*Per cent.*	*No.*	*Per cent.*	*No.*	*Per cent.*	*No.*	*Per cent.*	*No.*	*Per cent.*	*No.*	*Per cent.*	*No.*	*Per cent.*	*No.*	*Per cent.*	*No.*	*Per cent.*
0–9	0		17	10.1	58	7.8	39	7.7	7	3.8	2	6.7	0		0		123	7.4
10–19	1	17	50	29.8	253	34.2	143	28.3	44	24.2	5	16.7	6	33	1	25.0	503	30.4
20–29	4	67	55	32.7	217	29.4	150	29.7	70	38.5	10	33.3	7	39	1	25.0	514	31.0
30–39	0		27	16.1	117	15.8	92	18.2	30	16.5	7	23.3	0		2	50.0	275	16.6
40–49	1	17	11	6.5	61	8.2	40	7.9	17	9.3	2	6.7	1	6	0		133	8.0
50–59	0		4	2.4	14	1.9	18	3.6	6	3.3	2	6.7	3	17	0		47	2.8
60–69	0		3	1.8	13	1.8	14	2.8	4	2.2	2	6.7	0		0		36	2.2
70–79	0		1	0.6	4	0.5	7	1.4	3	1.6	0		0		0		15	0.9
80–89	0		0		1	0.1	1	0.2	0		0		1	6	0		3	0.2
90–99	0		0		2	0.3	1	0.2	0		0		0		0		3	0.2
100	0		0		0		0		1	0.6	0		0		0		1	0.1
Total	6	101	168	100.0	740	100.0	505	100.0	182	100.0	30	100.1	18	101	4	100.0	1,653	99.8

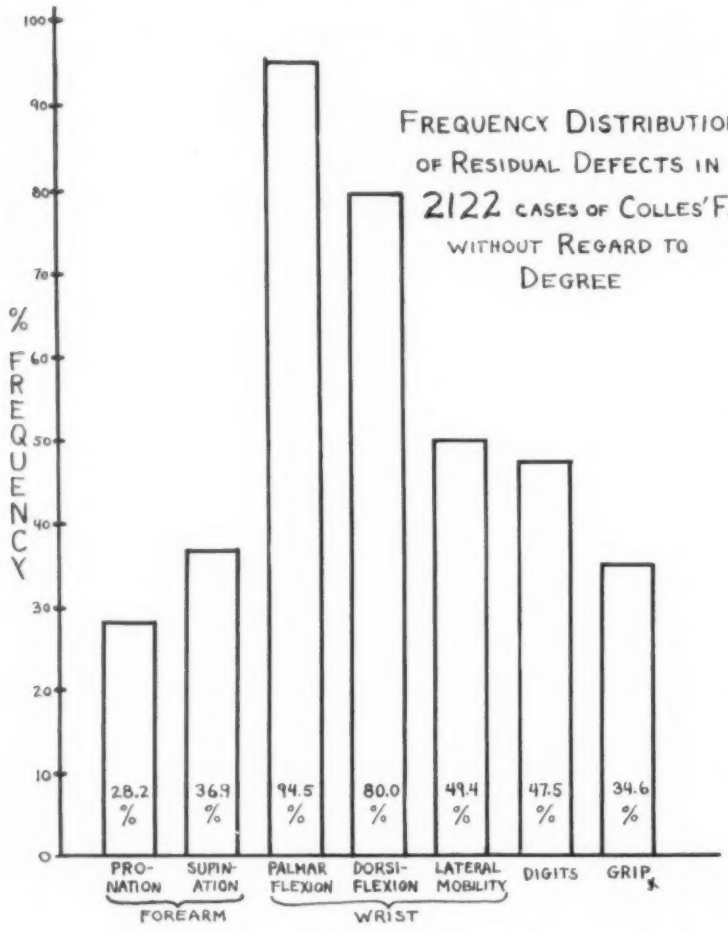

CHART VII

determining r, the coefficient of correlation.* This coefficient is a number which ranges from -1.000 to $+1.000$. Plus or minus 1.000 signifies perfect positive or negative correlation; 0.000 signifies an absolute lack of correlation. The value we found for r was $+0.0974$ which is considered to represent no statistically valid correlation. Further, we checked the validity of our figure for r by determining σ_r which was found to be less than one-third the

* Coefficient of correlation:

$$r = \frac{N\Sigma fdxdy - (\Sigma fxdx)(\Sigma fydy)}{\sqrt{[N\Sigma fx(dx)^2 - (\Sigma fxdx)^2][N\Sigma fy(dy)^2 - (\Sigma fydy)^2]}}$$

r = coefficient of correlation
N = number of cases = 1,653
f = frequency
x = abscissa (weeks of immobilization)
y = ordinate (percentage of disability)
d = deviation from most numerous (modal) group
dx = deviation along x axis $0 = 4$ weeks
dy = deviation along y axis $0 = 20$ to 29 per cent.
fx_a = total number of cases in "a" week of immobilization
fy_b = total number of cases in "b" disability percentile

$$r = \frac{7.66 \times 10^6}{7.86 \times 10^6} = 0.0974$$

Significance of r:

$$\sigma r = \frac{1 - r^2}{\sqrt{N-1}} = \pm 0.024$$

r, as greater than $3\sigma_r$, is significant.

value of r, therefore r is significant. We have sufficient data to substantiate the conclusion reached. Thus there is no correlation between the duration of immobilization and the percentage of disability in Colles' fracture, within reasonable limits.

The defects of function caused by Colles' fracture are those of pronation and supination of the forearm, movements about the wrist (palmar flexion, dorsiflexion, and lateral mobility), and flexion and extension of the digits about the metacarpophalangeal and interphalangeal joints.

In 2,122 cases of Colles' fracture, defect in pronation was present in 28.2 per cent., defect in supination in 36.9 per cent., defect in palmar flexion in 94.5 per cent., in dorsiflexion 80 per cent., and in lateral mobility 49.4 per cent. of the cases. It is obvious that by far the most frequent permanent defect was in palmar flexion, rather closely followed by limitation of dorsiflexion (Chart VII). The average limitation of motion in palmar flexion (of those having any defect) was approximately one-half the normal range, or a "moderate" defect. Dorsiflexion and lateral mobility had an average limitation which appeared to be slightly less than palmar flexion, although it could not be quantitated because of the arbitrary classification used in describing such defects. (The Workmen's Compensation Board findings for restriction of passive motion were classed as mild, moderate, marked, and complete to which we have given approximate values of one-fourth, one-half, three-fourths, or four-fourths loss of range of motion.) Pronation and supination showed a lower average defect much closer to mild restriction (one-fourth loss). These defects are probably not due, in any large measure at least, to any disuse atrophy of the muscles of the forearm since they are determined approximately one year after injury. Pronation and supination defects may conceivably be explained on the basis of a mechanical block to full movement caused by the enlargement of the bone due to callus formation, radial tilt, and shortening, since the only muscles relating to these motions which can be involved at the distal end of the radius are the pronator quadratus and the brachioradialis (supinator longus). There is considerable danger that the former could be disrupted anywhere beyond its origin, since it lies upon the radius. However, we have found that pronation was restricted in only one fourth of the patients, and in these, the restriction was most often mild. The brachioradialis may be involved since its insertion is on the radial styloid, but it plays a minor role in forearm supination. The flexores and extensores carpi are probably involved in or near the carpal tendon sheaths, and the mechanism is probably a traumatic synovitis with some adhesions. Flexion and extension defects in the wrist may also be due to loss of radial tilt and shortening of the distal portion of the radius with callus. These latter causes will also explain the defects in digit motion which were found to be present in almost one-half of the cases of Colles' fracture (47.5 per cent.).

The most frequent of all defects of the digits was in flexion of the distal phalanx of the index finger (43.6 per cent.). Flexion of the distal phalanges of the fingers (35 to 44 per cent.) was involved more often than either motion of any other joint. For any given joint, flexion defects were about twice as frequent as extension defects. The thumb was the digit least involved (20 per cent. of flexion and 9.4 per cent. of extension). Metacarpophalangeal joints (20 to 25 per cent. of flexion) were involved insignificantly more often than the proximal interphalangeal joints.

There was residual diminution of the grip in 34.6 per cent. of 2,130 cases of Colles' fracture. Only 3 per cent. of the total number of patients with Colles' fracture had an impairment which was classed as more than moderate; in 14.9 per cent. it was mild and in 16.7 per cent., moderate, with twelve (0.6 per cent.) showing complete loss of grip.

Non-union of Colles' fracture was extremely rare, being found in only four Colles' fractures (0.2 per cent.), but there were fourteen (0.7 per cent.) fractures which showed delayed union. Traumatic neuritis was extremely rare also, with only four cases of median-nerve involvement (0.2 per cent.) recorded, and only one case of ulnar-nerve involvement. There were three cases of causalgia (0.1 per cent.), as well as three cases of Sudeck's

atrophy (0.1 per cent.) and four of Dupuytren's contracture (0.2 per cent.). Persistent pain was noted in 2 per cent., and in 1 per cent. of the cases of Colles' fracture, limitation of shoulder motion was of significance.

Of 1,660 cases of Colles' fracture, there were 887 fractures of the ulnar styloid (53.2 per cent.), with 228 (13.7 per cent.) cases of non-union reported. Of the fractures of the ulnar styloid, 25.7 per cent. were, therefore, followed by non-union.

It has been stated above that the final Workmen's Compensation Board award was made approximately one year after the initial injury, by which time the residual defects were considered permanent. The lapse of time between injury and the Workmen's Compensation Board award in 1,055 cases was 12.0 months (mean, median, and mode), with a range of from four to fifty-one months.

DISCUSSION OF RESULTS

The first evident fact is the high incidence of Colles' fracture; it constitutes 1 per cent. of all Workmen's Compensation Board cases, and 60 per cent. of fractures of the radius. It is also a fracture with a low incidence of complications, which in this study included compound fracture, non-union and delayed union, navicular and ulnar-styloid fractures, neuritides, causalgia, Sudeck's atrophy, Dupuytren's contracture, limitation of shoulder motion, and persistent pain of the wrist. However, this fracture is not the benign condition many consider it to be. Cassebaum found no serious functional disability in his study of Colles' fracture, but we have seven patients in whom the loss of hand function was 90 per cent. or more, and over 3 per cent. of all the patients have disabilities of 60 per cent. or more. The average permanent loss of function of the hand in over 2,000 cases of Colles' fracture has been found to be 24 per cent. The percentage disabilities upon which this figure is based were adjudicated by the experienced physicians who compose the medical board of the Workmen's Compensation Board. In cases of doubt as to the fitting award, a panel composed of three senior Workmen's Compensation Board physicians was employed, and, as a final arbiter, the medical director of the Workmen's Compensation Board. Along the way, the patient's physician, insurance-company doctors, and independent experts were often called upon to aid in the judgment of the final award. Therefore, we may consider each award to be an accurate estimate of disability, based solely upon the deficits in function (range and power of motion) found at the final examination. As an estimate of the basis for such awards, here are the findings in a typical patient who was awarded 25 per cent. disability: moderate limitation of palmar flexion and dorsiflexion, mild limitation of lateral mobility, and mild flexion defects of the distal interphalangeal joints of the index, middle, and ring fingers, as well as an enlarged wrist.

However, it must be admitted that such defects as are most usually found are of minor importance for the unspecialized use of the hand; a loss of 50 per cent. of the range of motion does not imply a hand only half usable, for very seldom do we employ the full range of any joint motion. Even an ankylosed wrist is serviceable so long as the digits, especially the first two, are reasonably agile. Nevertheless, such considerations should not militate against the recognition of actual disability.

As to the correlations set up in the paper, little need be said. It was expected that increasing age would mean increasing disability, and that the greater the deformity, the greater would be the loss of function; but it is well to have support for such statements, especially since some authors have made different statements[1]. The one somewhat unexpected aspect was the lack of correlation between duration of immobilization and disability. Although the limit of immobilization was only sixteen weeks, it is the extreme one is likely to encounter, and within this range it was found that disability did not increase with the prolongation of the period of immobilization. The factors which we feel are of greatest importance in the effort to obtain an end result with a low disability are (1) accurate reduction, (2) adequate immobilization, and (3) early and persistent active motion.

CONCLUSIONS

From a study of a total of 2,132 cases of Colles' fracture from the files of the Workmen's Compensation Board, New York State Department of Labor, New York City District, the following conclusions were drawn:

1. Colles' fracture constitated 60.0 per cent. of fractures of the radius.

2. Incidence of Colles' fracture among Workmen's Compensation Board cases, New York City District, in 1945 and 1949 was 1 per cent.

3. Of all carpal fractures, that of the navicular constituted 70.8 per cent.

4. The ratio of males to females in Colles' fracture was 58 per cent. to 42 per cent. for 1945 and 1949, whereas the male-to-female ratio for all Workmen's Compensation Board cases for the same years was 84 per cent. to 16 per cent.

5. The left radius was involved in Colles' fracture in 55.1 per cent. of the cases; the right in 44.9 per cent. These figures include 0.94 per cent. of bilateral Colles' fracture.

6. The incidence of compound fractures among Colles' fractures was 1.3 per cent.

7. In 91.6 per cent. of the cases, the mechanism of injury was a fall on the outstretched hand.

8. A considerable proportion of Colles' fractures showed one or more of the following: comminution, impaction, and extension into the radiocarpal joint.

9. Reduction of Colles' fracture was performed in 88.3 per cent. Of the total number of fractures, 3.7 per cent. were manipulated a second time, and 1.0 per cent. required a third manipulation. In only 1.6 per cent. of the total was open reduction performed. Of the 11.7 per cent. in which no reduction was performed, it was our conclusion that almost one half required such manipulation.

10. In the 471 cases in which it was known that anaesthesia was given for reduction, local anaesthesia was used in 36 per cent. and general (gaseous and intravenous) anaesthesia in the remaining 64 per cent.

11. The average duration of treatment was four months.

12. Physical therapy was used in 96.6 per cent. of the cases, exclusive of active and passive motion. This varied widely in type, frequency, and duration, without appearing to affect appreciably the ultimate results.

13. The average (mean) percentage loss of function (disability) in all patients with Colles' fracture was 24 per cent. loss of the hand, based upon the findings of the Workmen's Compensation Board medical examiners. The range of disability was 0 through 100 per cent. Of all patients with Colles' fractures 94 per cent. had a resultant disability of less than 50 per cent. loss.

14. The mean age of all patients with Colles' fracture was 48.2 years; the median and mode were fifty years; the range was fourteen to seventy-eight years inclusive.

15. The age distribution in Colles' fracture has been found to be significantly higher than that of all Workmen's Compensation Board cases for 1945 and 1949. Of all Workmen's Compensation Board cases, 68.6 per cent. of the injuries occurred in people under the age of fifty, whereas 51.4 per cent. of Colles' fractures were in people of fifty or over.

16. The percentage of disability in Colles' fracture increased directly with age, at a rate of approximately 4 per cent. loss of function per decade.

17. Residual deformity (as an inverse measure of adequacy of reduction and immobilization) has been found to have a direct correlation with disability, at a rate of 10 per cent. loss of function per grade of deformity (none, mild, moderate, marked).

18. The duration of immobilization in Colles' fracture had no effect upon final residual disability.

19. The most frequent defect in passive motion about the wrist was in palmar flexion, present in 94.5 per cent. of the cases; defect in dorsiflexion was found in 80 per cent. Limitation of rotation of the forearm was present in one third and limitation of lateral wrist motion in one half the cases.

20. Forty-eight per cent. showed restriction of motion of the digits (flexion and extension), with flexion defects being twice as frequent as extension; the distal interphalangeal joints were most often afflicted, and the index finger was the most, with the thumb the least, often involved digit.

21. One third of the patients with Colles' fracture showed residual diminution of the grip which was mild or moderate in severity in all but 3 per cent. of the total number of cases.

22. Non-union of Colles' fracture was found in 0.2 per cent. and delayed union in 0.7 per cent. of the cases. Other complications included traumatic neuritis (0.2 per cent.), causalgia (0.1 per cent.), Sudeck's atrophy (0.1 per cent.), Dupuytren's contracture (0.2 per cent.), persistent pain (2 per cent.), limitation of shoulder motion (1 per cent.), compound fracture (1.3 per cent.), concomitant navicular fracture (0.5 per cent.).

23. Fifty-three per cent. of the cases of Colles' fracture were accompanied by avulsion fracture of the ulnar styloid, and of these latter, one-fourth remained ununited.

24. The interval between injury and final Workmen's Compensation Board medical examination and award was twelve months (mean, median, and mode).

NOTE: The invaluable aid of Miss Jeanette Hanlon and her Research and Statistics Section, Workmen's Compensation Board, and of Miss Doulan, is gratefully acknowledged.

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DISCUSSION

THE USE OF IPRONIAZID IN THE TREATMENT OF BONE AND JOINT TUBERCULOSIS

(*Continued from page 625*)

rate from injections into the sinuses, abscesses, or cavities is so uncertain that proper blood levels cannot be controlled. Oral administration, to treat the patient's body as a whole, is the best and the safest.

For the same reasons the dosage should not be increased above 4 milligrams per kilogram of body weight except for very short times and with the realization that patients will become toxic. If you have a patient who is dreadfully ill, you may be scared into trying 6 milligrams per kilogram of body weight. Within twenty-four hours you will find that patient neurotoxic. If you continue to push this higher dosage, you are in danger of causing the development of a psychosis. Injection of material into a patient on a satisfactory oral dosage has been found to upset the balance and cause toxicity.

Local treatment will not touch tubercle bacilli buried in the calcified lesions or in sloughed-off pieces of abscess wall. The drug must be circulated in a definite concentration that will destroy the *Mycobacterium tuberculosis* and not damage living tissue cells.

Even with a proper dosage you have to watch for toxicity. You can forget all other manifestations of toxicity, if you will examine the patient every day as to reflexes. If these become severely hypertonic, even though there is no clonus, the drug dosage should be decreased.

Do not use the drug in combination with streptomycin at present. You will confuse yourself as to toxicity and results. Other qualified investigators are working this problem out. Await their reports. Remember you cannot use it at half dosage. Do not experiment as regards dosage; watch your patients and you will find this material a great help in the treatment of bone and joint tuberculosis.

THE JUVENILE AMPUTEE *

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The juvenile amputee is defined as being under twenty-one years of age and having undergone a surgical amputation or having a congenital anomaly necessitating the use of a prosthesis. Children falling within this category came under the authors' supervision in the early fall of 1946.

Most of the patients were referred to us by practitioners of medicine, either on a private basis or through orthopaedic clinics throughout the State of Michigan. These cases represent the surgical results of general practitioners, surgeons, and orthopaedic surgeons. The children with congenital amputations reflect the variations in management with respect to age of fitting and the types of prostheses.

This analysis has been made possible by the inauguration of the Juvenile Training Center and is the culmination of five and one-half years' observation.

The total number of cases of amputation was 192. Of these, 128, or 66.6 per cent., were surgical amputations, and sixty-four, or 33.3 per cent., were congenital amputations. There were 137 males (71.3 per cent.) and fifty-five females (28.7 per cent.). The average age at which surgical amputation was performed was eleven and one-half years.

TRAINING PROGRAM

The initial examination is performed in the out-patient clinic. Included in the history is a mental evaluation. The stumps are inspected for length, scar placement, and circumference. Abnormal skin conditions are recorded. The mobility of proximal joints, contractures, and the presence or absence of tender areas are determined.

If the child has a prosthesis, he is asked to demonstrate how he can use it. Following a functional evaluation, recommendations are made for adjustments, repair, or discard. The advisability of corrective surgery is considered at this time. If the prosthesis is to be refitted, the patient is sent immediately to the limb shop. Should gait-training or arm-prosthesis instruction be necessary, the amputee is admitted to the training unit. If not, an out-patient status is maintained.

The new amputee is placed on a schedule of physical therapy while he is awaiting a new appliance. Physical therapy corrects contractures and builds strength in muscle groups. The therapist instructs the patient, if he is old enough, in the proper care of the stump and endeavors to bring about coordination of motion and balance. Occupational therapy is of particular value in upper-extremity amputation. The basic skills developed in physical therapy are channeled toward the coordination and practical function which mark the well trained amputee.

The prosthetic instructor works in close cooperation with the physical and occupational therapists. He supplements their work by teaching the child to apply the principles of muscle coordination so that he can use his artificial limb in a dexterous manner. As the child progresses, he is initiated into the practical skills which everyday living demands.

Early in the program the patient wears a limb which has been fitted accurately but has not been "finished off". The finishing is completed when personal adjustment has been judged satisfactory.

The importance of complete cooperation between the prosthesis fitter and the surgeon cannot be overemphasized. The limb fitter must have patience with both the surgeon and

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TABLE I

CAUSES OF SURGICAL AMPUTATIONS

Explosions	31
Vehicular accidents	25
Power-tool accidents	17
Tumor	16
Infection	16
Railroad accidents	14
Thermal injury	5
Poliomyelitis deformity	1
Osteogenesis imperfecta	1
Pseudarthrosis of tibia	1
X-ray irradiation (growth retardation)	1
Total	128

the amputee. He must be willing to make repeated adjustments and to pay close attention to details. A child will not wear an uncomfortable limb or one which is not mechanically sound. The fitter must have flexibility of mind; he must have imagination and be able to accept suggestions. If these qualities are not present, satisfactorily fitting prostheses are occasional good fortune, not planned results.

During residence in the training unit, the child is afforded educational and recreational facilities. He is in his current school grade and his diversional activities augment prosthetic training. In-patient training periods vary from one week to many months. The average has been forty days.

Clinical follow-up has been accomplished in the out-patient departments. Experience has taught that three-month intervals are optimum. Children adjust to prostheses very quickly; the appliance becomes much more a part of them than it does in adults. The extreme physical activity of a child, however, takes its toll in wear and tear. Minor adjustments of moving parts, limb lengthening, and harness repair at frequent intervals will prolong the life of the prosthesis. The problems of growth are ever present and the prostheses require lengthening, fitting of liners, or bucket tooling. In teen-aged girls the correction of calf sizes and matching of flesh color are important.

SURGICAL AMPUTATIONS

There were 102 males and twenty-six females with surgical amputations. The levels of amputation were distributed as follows:

Lower extremity:		Upper extremity:	
Above the knee	38	Above the elbow	22
Below the knee	31	Below the elbow	25
Bilateral	10	Bilateral	2

The causes of surgical amputations are shown in Table I.

Eight of the amputations were performed by the authors. This figure represents 6.2 per cent. of the total number of surgical amputations. All other amputations were performed elsewhere.

The usual problems and complications besetting the amputee have been studied, including positioning and extent of scar, spur formation, neuroma formation, short stumps, overgrowth, and painful phantom limb. Startling differences are evident when the juvenile amputee is compared with the adult.

Scar Formation

A wide variety of scars has been observed. They have ranged from perfect, thin, non-

adherent, atrophic scars to multiple, extensive, inelastic scars typical of old chronic osteomyelitis. In no case to date has any patient required revision for the removal of scar. All patients with surgical amputations have been fitted with prostheses and have worn them without breakdown. There have been two cases of skin-grafting which have offered no complication in the wearing of prostheses. These observations would seem to indicate that extensive or poor placement of scar in either upper-extremity or lower-extremity stumps is not reason *a priori* for stump revision.

Spur Formation

There have been no complications due to spur formation in this series. In no case has it been necessary to perform a surgical procedure for removal of a spur. Some degree of spur formation was the rule rather than the exception.

Neuromata

Of the 128 patients with surgical amputations, only five (3.7 per cent.) were found to have neuromata producing symptoms sufficient to warrant surgical interference.

One patient refused surgical resection. The others were as follows:

Level of Amputation		*Site of Neuroma*
Above the elbow	Amputation at fourteen years	Radial nerve
Below the knee	Amputation at eight years Symptoms at nineteen years	Peroneal nerve
Above the knee	Amputation at fifteen years Symptoms at eighteen years	Femoral nerve
Below the elbow	Amputation at twelve years Symptoms at fourteen years	Median nerve

Short Stumps

It is difficult to define a short stump. It is a matter of degree relative to the conception of the ideal stump length. In the lower extremity it is universally one which offers the optimum function with sufficient lever, muscle power, and minimal scar. The criteria may be said to be the same for the upper extremity. An amputation performed at the site of election is expected to be ideal. In the presence of trauma of varying degrees, expediency and life-saving measures predominate in the surgeon's decision. A good number of these traumatic cases fall within the latter category. In this group of children no refashioning or tendon sectioning has been done. It is our feeling that extremely short below-the-knee, below-the-elbow, and short thigh stumps can be fitted and made functional. The short above-the-elbow stump presents problems relative to satisfactory function. Experience with three cases has indicated to us that it is possible to fit a satisfactory prosthesis to above-the-elbow amputees without an extensive bulky shoulder harness. With training, these children can be taught to flex the forearm from an extended position without an obvious homolateral shoulder thrust. Children adapt themselves to short humeral stumps and have more mobility at the shoulder joint. They can open the hook with the elbow locked at right angles.

Overgrowth of Bone

Overgrowth is a phenomenon peculiar to the younger amputee. The humerus is more liable to overgrowth than the bones of the forearm, while the femur seldom overgrows to a point necessitating surgical interference. The fibula tends to overgrow the tibia. This complication in the younger amputee may be met at the initial amputation by sectioning

the fibula higher than the tibial stump or by effecting a synosteosis operation. Extirpation of the fibula has been done but seems to offer no advantage over short resection or synosteosis. Eight stumps to date have been refashioned because of overgrowth: three humeri, four tibiae, and one fibula. It is interesting to note that four of these overgrowths have been in negro children.

One stump has been refashioned because of the development of an adventitious bursa at the end of the tibial stump. This occurred in a child with spina bifida, thirteen years of age, in whom the amputation had been performed at eight years.

FIG. 1

Nine-year-old child with a double-fulcrum multiplying-action elbow joint.

Phantom Limb

Phantom limb was present in those children whose amputations were done during their early teens. Forty children have been questioned over a period of three years. Thirty were able to conjure up their extremities. The average age of this group was eleven and one-half years. The average time since amputation was two years. Twelve children unable to "call up" the extremities were under ten years in most instances and the time since their amputation varied from one to thirteen years. In no case has there been complaint of a painful phantom limb. It would seem that the "sensory counterpart" in the younger child is not fixed in the psyche and is forgotten.

CONGENITAL AMPUTATIONS

There were thirty-five males and twenty-nine females with congenital amputations. The levels of amputation were distributed as follows:

Lower Extremity:		Upper Extremity:	
Above the knee	4	Above the elbow	0
Below the knee	17	Below the elbow	31
Bilateral	$8\frac{1}{2}$*	Bilateral	$2\frac{1}{2}$*
	Quadruple 1		

The group of patients with congenital amputations may be divided into those not needing amputation and those whose anomalous extremity was surgically modified to accommodate a prosthesis. Primary limb-fitting for anomalous extremities was done in forty-four cases; surgical conversions (amputations) were undertaken in twenty cases. The conversions were performed to produce a more satisfactory stump for prosthetic fitting.

Scars, neuromata, bone overgrowth, and neurovascular complications have not been

* The $\frac{1}{2}$ denotes a bilateral case; lower extremity on one side, upper on the opposite.

major problems in the group with congenital amputations. Amputation (conversion) often means the removal of the vestigial remnant of an extremity. Usually there are no major nerve trunks involved.

A characteristic abnormality is the absence of the forearm and hand with a very short below-the-elbow stump. This anomaly has been seen in twenty patients, twelve girls and eight boys. In most instances they have been seen shortly after birth by various practitioners of medicine. Of these twenty patients only one had a prosthesis when he was first seen, and yet the average age of the group was thirteen years. The youngest child was three, the oldest twenty years. The older children had learned to use their stump in a very dexterous manner. Such activities as knitting and sewing were accomplished with ease. All of these were grateful to have been fitted with a prosthesis.

A stump less than three inches in length is routinely fitted with a double-fulcrum, multiplying-action elbow joint (Fig. 1). This appliance is of inestimable value in utilizing the motion of the extremely short stump. For every degree of the stump bucket's motion, the prosthetic forearm moves 2.5 degrees, thus increasing the range of motion by two and one-half times. As a result of this, the hook can be brought easily to the patient's face and mouth, which would not otherwise be possible.

The optimum time for applying a prosthesis to a child with an amputation of the upper extremity seems to be four years, one year prior to formal schooling (kindergarten). Few children with upper-extremity handicaps before this age can button shirts, tie shoe strings, or carry a pocket book. At four years of age the mental organization and kinaesthetic sense assert themselves and the patient will be able to put the appliance to proper use. Trials on children younger than four have been failures. The limb hangs by the side and is non-functioning. The child cannot be expected to perform beyond his years in motor accomplishments.

The conversion of a hypoplastic anomaly below the knee requires careful planning. A seven-year-old girl had been operated upon elsewhere for such an anomaly. The surgeon had elected to do a Gritti-Stokes operation in an endeavor to produce an end-bearing stump. The growth problem apparently had not been considered and, when she was seen by us two years later, the child did not have an end-bearing stump. The distal femoral epiphysis had been destroyed or arrested through the fixation by two screws. The girl is now nine years of age, and the amputation is clinically at low-thigh level; as growth continues, it will be at least at mid-thigh level.

A more likely procedure in the case of anomalous limbs below the knee is disarticulation. One such patient, with a bilateral amputation performed elsewhere, has been followed for five years. The thighs remain equal in length and the lever arms continue to grow.

These two cases clearly demonstrate the advantage of preserving the distal femoral epiphysis, if possible, in the conversion of a below-the-knee to an above-the-knee amputation in young children.

TYPES OF PROSTHESES

Prosthetic problems have not been difficult. In general, conventional limbs are used. Willow wood seems to be the material of choice for buckets. The efficiency of a prosthesis depends upon the proper fit and comfort. Suction sockets have been used in thirty-three cases for the above-the-knee amputee. Three of these had bilateral amputations. Of these cases only one has been a failure. This was a nineteen-year-old girl who had had amputation at seventeen years. She was referred for a new limb and for training in walking. Under supervision, she learned to walk well. When her prosthesis was changed to a suction socket one year later, she persisted in showing a positive Trendelenburg on the amputated side. When she was put back into a conventional above-the-knee appliance with a pelvic band, she walked with a smooth, well balanced gait.

We do not think final conclusions can be drawn for suction sockets in children. It

has been our experience that they have produced stump hypertrophy and increased redundancy of soft tissues.

The case of a twelve-year-old boy, however, emphasized the virtues of the suction socket in short stumps for children. His amputation had been performed after a railroad accident. He presented an extremely short femoral stump with four to five inches of a redundant soft-tissue mass. A suction socket was fitted and resulted in a good gait, despite an extremely short lever arm. It is our feeling that the soft-tissue mass increases the mobilization of the prosthesis.

In patients with congenital deformities resulting in shortening and angulation of a lower extremity whose parents refuse surgical conversion, modified conventional appliances have been employed. Molded leather foot buckets and open lace cuffs will support and disguise the abnormalities. It is believed, however, that these modified prostheses are less satisfactory than the conventional appliances. As growth continues and bony prominences develop in skeletal parts, friction and pressure to overlying skin will complicate the problem. Surgical amputation or disarticulation are methods of choice and should be planned to include a long period of care.

SUMMARY

One-hundred and ninety-two children have been studied in a Juvenile Training Program. Of 128 surgical amputations, revision for extensive or poorly placed scar was not necessary. There have been no tenotomies or re-amputations to further mobilize stumps. Bone overgrowth requiring surgical correction has been encountered in eight cases to date. Four neuromata have been sufficiently discomforting to be removed. There have been no operations for removal of spurs. Suction sockets, when properly fitted, in children are superior to the conventional above-the-knee prosthesis.

DISCUSSION

Dr. Atha Thomas, Denver, Colorado: This, in my opinion, is a most worth-while paper. Experience with so many cases of amputation in children is indeed rare for the average surgeon, and the literature on this particular phase of amputation is meager.

Decisions on the desirability of carrying out definitive amputation surgery in children with marked shortening and deformity resulting from severe congenital defects are often difficult. Also, the selection of the proper prosthetic device for juvenile amputees and determination of the best time for fitting them presents serious problems. It is my opinion that in many such cases it is far preferable to carry out early radical surgery, carefully designed with due consideration for prosthetic requirements, for example, the amputation of a useless foot in a very short leg, followed by the fitting of a conventional artificial limb, rather than the attempt to use a complicated, bulky, unsightly extension shoe and brace on the shortened and deformed limb.

I am in complete agreement with the speakers' statement that prostheses for both upper-extremity and lower-extremity amputees should be fitted to these children as early in life as possible, so that the child grows up with his prosthesis and it becomes an integral part of him.

I am also impressed with the value of thorough training in the use of the prosthesis in these juvenile cases, especially in the upper-extremity amputee, and with the necessity for frequent follow-ups for inspection, adjustment, and necessary repairs of the prosthesis, as was emphasized by the authors.

Dr. Jerome Lawrence, New York, N. Y.: The prime characteristic of the juvenile amputee whose amputation takes place during the growth period is later atrophy and hypoplasia of soft tissue and bone. The treatment for this is early application of a prosthesis and restitution of function. One of the most difficult problems in applying a suction-socket prosthesis to the adult is hypoplasia and atrophy of the muscles of the above-the-knee stump. This is encountered when the child has not had the opportunity to use a prosthesis early in life. The early application of a suction-socket prosthesis does more to counteract hypoplasia of muscle tissue of the thigh than the conventional type of prosthesis. It makes the muscle hypertrophy and augments growth of bone. However, in the application of the suction-socket prosthesis to a growing child, it is necessary to have frequent follow-up visits. As changes in the stump take place, it will be necessary to correct the socket, since a suction-socket prosthesis requires a perfect fit.

I have found this paper very interesting and instructive.

PRIMARY TORSIONAL FRACTURE OF THE RADIUS OR ULNA

BY MICHAEL BURMAN, M.D., NEW YORK, N. Y.

From the Hospital for Joint Diseases, New York

This is the second of a series of papers on the mechanics of the forearm. The first [3] discussed the mechanical events which followed the operation of induced pseudarthrosis of the radius in congenital radio-ulnar synosteosis. This operation, actually an induced torsional ostectomy of the radius, demanded the analysis of primary torsion of the radius (or ulna) in the general situation. This will be given elsewhere [4] in a study on paralytic supination contracture of the forearm and the torsional osteotomy of the radius or ulna which pronates the forearm. The following paper discusses the primary torsional fractures of the radius and ulna which follow an externally applied torsional force, with comments on secondary torsion of the radius by muscle pull. The thread of the writer's thought ends in the concept of paired-joint motion, specifically applied to the forearm in this paper and in the papers on paralytic supination contracture of the forearm and the so-

FIG. 1-A

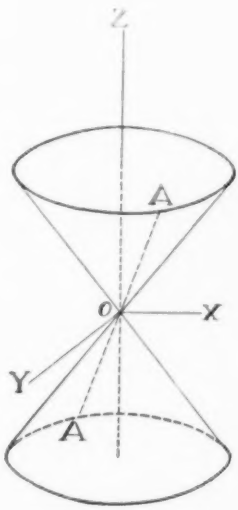

FIG. 1-B

FIG. 2

Fig. 1-A: The physiological cone is generated by the revolution of the mechanical triangle of the forearm (triangle *EFG*). The line, *EG*, which joins the center of the head of the radius with the center of the head of the ulna is the mechanical axis or fixed leg of the right triangle. The hypotenuse is the longitudinal axis of the radius. The rotating leg, *FG*, the line of the articular surface of the radius prolonged to the mid-point of the ulnar head, makes a right angle with the fixed leg. (Reproduced by permission from *Bulletin of the Hospital for Joint Diseases*, Vol. 13, p. 304, 1952.)

Fig. 1-B: A cone is the surface made by the revolution of a straight line passing through the origin of a three-coordinate system and making a given angle with the axis about which it is swung, in this case, the Z-axis. (This diagram is modified from Figure 140 in *Elementary Calculus*, by F. S. Woods and F. H. Bailey [12].) In a more limited meaning, a cone is swept out by the hypotenuse of a right triangle the fixed leg of which is the axis of motion. (Reproduced by permission from *Bulletin of the Hospital for Joint Diseases*, Vol. 13, p. 303, 1952.)

Fig. 2: The mechanical triangle, *ABC*, is the right triangle of a family of triangles with a common side, *AB*. It is never similar to or equal to the anatomical triangle in supination, *ABD*. The rotation of the mechanical axis *BC* through the arc *CE* cuts the ulna at the coronoid process. The length of the mechanical axis equals the effective length of the ulna. (Reproduced by permission from *Bulletin of the Hospital for Joint Diseases*, Vol. 13, p. 305, 1952.)

FIG. 3

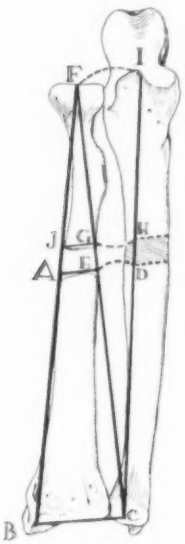

FIG. 4

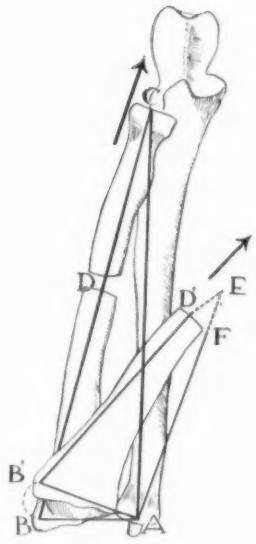

FIG. 5

Fig. 3: The by-passing operation in congenital proximal radio-ulnar synosteosis creates a new proximal radio-ulnar joint by resection of a segment of the radius below the synosteosis. The forearm is looked at from below and toward its volar side. The half cone is generated only in a volar direction. The distal end of the radius, as it generates the cone, angulates dorsally and ulnarly. (Reproduced by permission from *Bulletin of the Hospital for Joint Diseases*, Vol. 13, p. 309, 1952.)

Fig. 4: A new proximal joint has been established in the (synosteotic) radius at *A*. The ulna becomes longer than the radius. It is necessary to shorten the ulna to re-establish length equivalence between the two bones the dysequivalence of which is made manifest by radial deviation of the hand and ulnar deviation of the osteotomized distal part of the radius and the mechanical axis. Since the mechanical triangle, *ABCE*, is incomplete, a frustum of a cone is generated by the revolution of *AB* about *CE*, the distal mechanical axis. The proximal part of the radius, *FJ*, is fixed, and cannot rotate about the proximal mechanical axis, *FG*. To measure the excess length of the ulna, drop a perpendicular, *AE*, from the proximal end of the freed radius to the mechanical axis. *CE* rotated cuts the ulna at *D*. *CE* equals *CD* which is the distal effective length of the ulna. *FG*, with *F* as the fixed center, transects the ulna at *H*. *FG*, with *G* as the fixed center, cuts the ulna at the coronoid process or *I*. *HI* is the proximal effective length of the ulna. The shaded segment, *DH*, is the excess length of the ulna. This is true for any position of the mechanical triangle, since the mechanical axis which can move is a radius of a circle with its center at *C*, the center of the ulnar head. (Reproduced by permission from *Bulletin of the Hospital for Joint Diseases*, Vol. 13, p. 308, 1952.)

Fig. 5: The radius has been cut at *D*. The incomplete mechanical triangle tilts ulnarly on the fixed point of the center of the ulnar head. A frustum of a cone is generated. The mechanical triangle is completed by the proximal growth of the new radius. The mechanical block of the synosteotic radius deviates the growing radius ulnarly. The triangle is completed and a frustum of a cone surmounted by a cone is generated. The growth of the new radius is such that it is never the length of the original radius, *BC*. The arrows indicate the direction of growth of the original radius and the new radius. (Reproduced by permission from *Bulletin of the Hospital for Joint Diseases*, Vol. 13, p. 311, 1952.)

called luxation of the head of the ulna. Finally, the concept of paired-joint motion is generalized and applied to the solution of the problem of low-back pain and scoliosis.

The mechanical axis of the forearm (Fig. 1-A) is the line which joins the center of the head of the radius and the center of the head of the ulna. It is the stable leg of the right triangle of which the hypotenuse is the axis of the radius and the rotating leg of which is the base of the radius extended to the center of the ulnar head. The rotation of the radius generates a cone (Fig. 1-B) or more properly a half cone which is volarly placed. The vertically paired proximal and distal radio-ulnar joints move synchronously. (This pairing is vertical, for one joint is placed above the other, in contradistinction to the horizontal pairing of the apophyseal joints of the spine.) The head of the ulna moves dorsally in pronation and volarly in supination.

The rotation of the mechanical axis on the fixed point which is the center of the ulnar

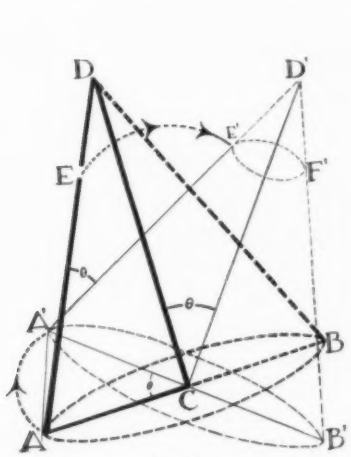

FIG. 6

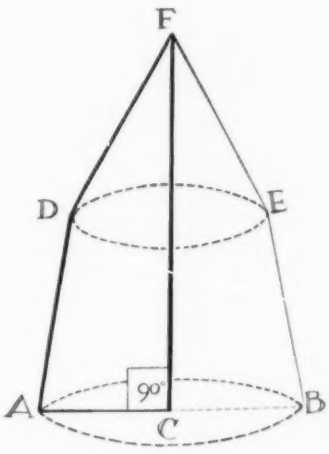

FIG. 7

Fig. 6: The cone *ABD* is the physiological cone of revolution. The radius is then cut at *E*. The new radius, *AE*, tilts ulnarly through the angle Θ to *A'E'*. The mechanical triangle rotates ulnarly through the angle Θ, the fixed point of rotation being the center of the head of the ulna. Since the mechanical triangle becomes incomplete by the section of the radius, a frustum of a cone, *E'F'A'B'*, is generated. In time, the mechanical triangle is completed by the growth of the proximal end of the new radius and a cone is generated. In this diagram, the new cone, *A'B'D'*, is made congruent to the physiological cone, *ABD*. This cannot take place, for the proximal synosteotic radius blocks the growth of the distal radius. (Reproduced by permission from *Bulletin of the Hospital for Joint Diseases*, Vol. 13, p. 315, 1952.)

Fig. 7: The frustum surmounted by a cone. (Reproduced by permission from *Bulletin of the Hospital for Joint Diseases*, Vol. 13, p. 315, 1952.)

head cuts the ulna at the coronoid process. The length of the mechanical axis equals the *effective* length of the ulna, or the length of the straight line joining the mid-part of the coronoid process with the center of the ulnar head. A length equivalence is thus established between the radius and the ulna (Fig. 2).

Sometimes it is necessary to establish a new paired-joint system, either for the moment, as during a corrective osteotomy, or permanently, especially when the proximal radio-ulnar joint is fixed because of synosteosis. A fundamental rule of paired-joint motion states that restraint or abolition of one joint of a pair restrains or abolishes motion of the other.

A permanent, new paired-joint system is desirable in proximal congenital radio-ulnar synosteosis. This can be achieved by the by-passing operation which makes a neo-arthrosis below the synosteosis (Fig. 3). As discussed in a previous publication, the mechanical axis of this new paired-joint system is the line which joins the center of the new joint with the center of the ulnar head (Fig. 4). At any level of section, there is ulnar angulation of the radius by reason of the greater length of the ulna. This ulnar angulation of the radius is the greater, the more distal the level of its section. The mechanical axis is also tilted ulnarward (Fig. 5). The ulna is therefore shortened to re-establish length equivalence in this operation. Rotation of the forearm then generates the frustum of a cone which approximates the physiological cone if the radius is cut as high as possible (Figs. 6 and 7). Finally, since the radius is an element of the volarly placed cone, it angulates dorsally as well as toward the ulna.

A temporary new paired-joint system is created by torsional osteotomy of the radius in fixed paralytic supination contracture of the forearm. The mechanical axis joins the center of osteotomy with the center of the head of the ulna. Since the ulna is not ordinarily shortened, the rotation of the radius into pronation angulates the radius ulnarly and dorsally, except when the radius is so long that its torque gives length equivalence between the two bones.

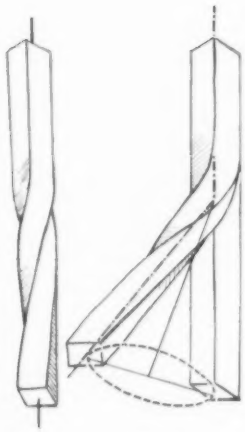

Fig. 8 Fig. 9

Fig. 8: Axial twist of a rod of rectangular cross section about its longitudinal axis.
Fig. 9: Non-axial torsion of a straight rod.

The angle of ulnar angulation is less, the more proximal the level of osteotomy. The radius heals in a twisted or torqued position. The angle of torque of the radius in paralytic supination contracture after osteotomy of the radius is 180 degrees, or half a circle.

In either case the radius must angulate ulnarward, because it is an element or generator of the conical surface (Figs. 1-B and 3).

The nature of torsion itself needs discussion. A bone is torqued about a fixed point of torque or twist either axially or non-axially. In axial torsion, the longitudinal axis of the fixed fragment remains collinear with the longitudinal axis of the fragment which is turned about the stable point of twist (Fig. 8). Axial rotation, which is the analogue of axial torsion, is the characteristic of a one-bone, paired-joint system, a good example of which is the clavicle joining the paired acromioclavicular and sternoclavicular joints. In non-axial torsion, the longitudinal axis of the fixed fragment is not collinear with the longitudinal axis of the turning fragment in which any most distal point describes a circle. The figure generated in space by the moving fragment is a cone (Fig. 9). Non-axial rotation is the characteristic property of the vertically paired joints of a two-bone system, a typical example of which is the paired radio-ulnar joints of the forearm. Non-axial torsion, either pathologically induced as in fracture or deliberately by osteotomy, is the analogue of non-axial rotation (circumduction).

In any torque, *half torsion* takes place if the lower half of a rod or bone is twisted on its fixed upper half, or conversely. This concept is important, for in all the examples cited in this paper, the proximal half of the bone does not itself twist. It is the distal half of the bone which is twisted.

The point of torque is constant in a given case, for it is the point at which twist takes place. The spiral line of fracture follows the direction of twist and hence indicates this direction. Its most proximal point is the point of torque.

Whole torsion takes place when each half of a rod is twisted in opposite directions, a concept important to remember in scoliosis.

With these concepts in mind the mechanism of primary torsional fractures of the forearm can be understood more readily. This uncommon fracture follows an active twisting force applied to the forearm distally, a force which demands a greater rotation of the forearm in supination or pronation than is physiologically possible.

Four situations of torque are possible:

1. *The radius undergoes non-axial torsion.* The point of torque is more distal than proximal, since the force is applied distally. The radius, which is the moving bone, breaks spirally, since a spiral line of fracture is the expression of the strain of twist. (The reader may twist a tongue blade, holding one end fixed, to confirm this.) The inferior radio-ulnar joint is disrupted. In hyperpronational twist, the ulnar head is displaced dorsally; in hypersupinational twist, the ulnar head is moved volarly. The movement of the ulnar head is the exaggeration of the normal dorsal movement of the ulnar head in pronation and of its volar movement in supination. Actually, only the radius breaks spirally by hyperpronational movement. The author has not seen a torsional fracture of the radius due to hypersupination.

Reduction of the fresh torsional fracture follows the simple manoeuvre of untwisting the bone. The forearm is supinated in fracture by pronational twist, the bones regaining

FIG. 10-A

FIG. 10-B

FIG. 11

Fig. 10-A: Torsional fracture of the right radius by a hyperpronational force. The line of fracture is spiral and the direction of the fracture line reveals the direction of force. The radius is ulnarly angulated and hence shortened. The longer ulna thrusts the hand radially. The inferior radio-ulnar joint was disrupted and the ulnar head thrust dorsally. This roentgenogram was made on July 15, 1951, a few hours after injury.

Fig. 10-B: Roentgenograms made January 16, 1952. The fracture healed in good position, length equivalence between the radius and ulna having been restored by supination of the forearm. This manoeuvre reduced the disrupted inferior radio-ulnar joint at the same time.

Fig. 11: Roentgenograms made December 18, 1950, showing the dorsal and ulnar angulation of the radius after osteotomy of the radius to pronate the forearm in fixed paralytic supination contracture.

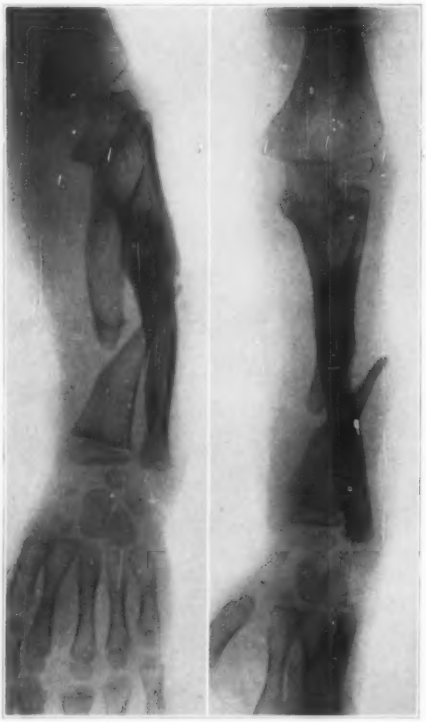

FIG. 12

FIG. 13

Fig. 12: Roentgenograms of December 17, 1948. A segment of the radius had been resected on March 1, 1947, below the left congenital radio-ulnar synosteosis (operation of by-passing neo-arthrosis) and each stump had been capped with a cup of lucite. The periosteum was locally resected. A segment of ulna was removed on April 10, 1948, to give length equivalence between the radius and ulna. The ulnar angulation recurred. The distal fragment angulated dorsally by reason of the volar tilt of the cone of revolution. (Used by permission of the *Bulletin of the Hospital for Joint Diseases.*)

Fig. 13: Roentgenogram of October 13, 1949. Combined ostectomy of the radius (the by-passing operation) and resection of an equal segment of the distal part of the ulna were done on August 9, 1948. Since there was length equivalence between the radius and the ulna, the radius did not angulate ulnarly. However, it angulated dorsally. (Used by permission of the *Bulletin of the Hospital for Joint Diseases.*)

length equivalence. The ulnar head is automatically reduced. In old fractures which have healed in the twisted position, an osteotomy is needed to detorque the radius and, if the ulnar head cannot be reduced, it should be resected.

CASE 1. A woman, fifty years old, caught her right forearm in a washing machine on July 15, 1951, as it became entangled in the folds of a tablecloth which she was pulling out of the machine. The forearm was hyperpronated with considerable force for about two minutes until her maid stopped the machine. She was seen two hours after the accident. The hand was radially deviated by the longer ulna. The ulnar head was prominent dorsally by diastasis of the inferior radio-ulnar joint. The forearm was pronated and the radius, broken spirally in its lower third, was angulated ulnarward and hence shortened. The roentgenograms of the forearm confirmed the torsional fracture of the radius and the separation of the distal radio-ulnar joint (Fig. 10-A). The fracture was reduced under general anaesthesia by supination of the forearm. This simple manipulation lengthened the radius by detorquing it and reduced the head of the ulna.

The plaster was removed on August 29, 1951. The patient was then given physical therapy. A stellate-ganglion block was done on September 8 to abolish swelling and stiffness of the hand and fingers. Treatment was discontinued on November 27. When the patient was seen again on January 16, 1952, the fracture was well healed (Fig. 10-B). She complained of vague pain on the ulnar side of the ulnar head and of some stiffness of the fingers. The appearance of the forearm was normal and the ulnar head was in good position. Supination

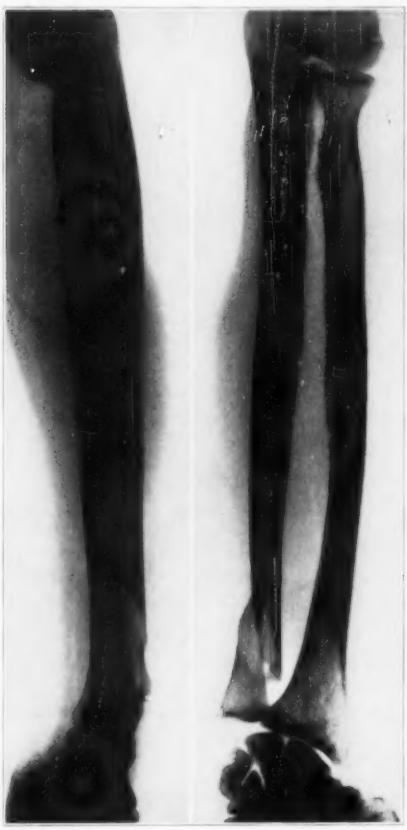

FIG. 14

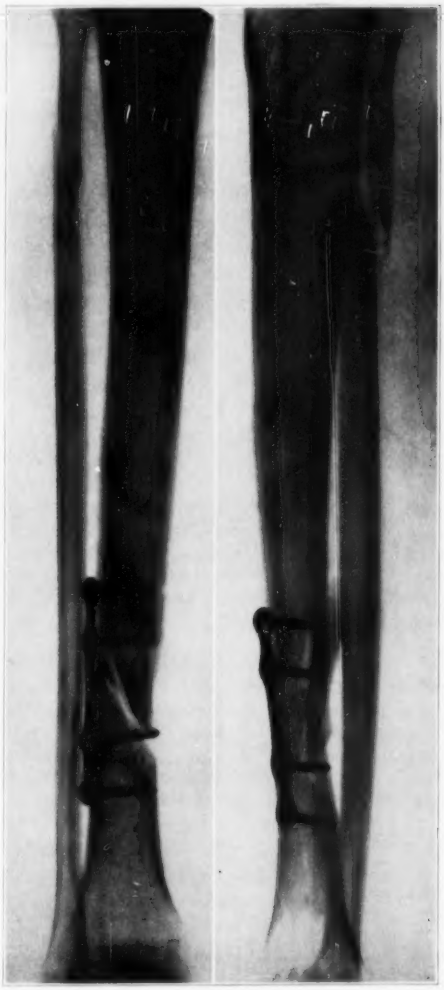

FIG. 15

Fig. 14: Spiral fracture through the neck of the left ulna by forced supination of the left forearm. This roentgenogram was made on February 15, 1951, a day after injury. Note that the forearm is supinated.

Fig. 15: Roentgenogram of a spiral fracture of the tibia and fibula nine weeks after injury. The tibia has broken distally and the fibula proximally, the point of torque being either the fixed knee joint or a point just below it. The fracture lines, being collinear except for the interruption of the interosseous membrane, run in the same direction in the anteroposterior view. The lines of fracture are parallel in the lateral view. The direction of torsion is decided by the direction of the spiral line of fracture.

of the forearm reached 85 degrees and pronation 75 degrees. Because of lax ligamentous structures, both hands could be rotated about 10 degrees farther in both supination and pronation. Finger motions were full and easy. The right grip measured thirty-six pounds and the left forty-four pounds in this right-handed person.

Deliberate torsional osteotomy of the radius to pronate the forearm in paralytic supination contracture or osteotomy to supinate the pronated forearm of congenital proximal radio-ulnar synosteosis is the equivalent situation. Thus, after osteotomy of the radius to correct a paralytic supination contracture of the forearm, the distal fragment angulates ulnarward and dorsally by non-axial torque. A roentgenogram (Fig. 11) showed the torqued and angulated bone after such an osteotomy. The angulation of the radius is

Fig. 16

Fig. 16: A diagram of a supinated right forearm illustrating the presumptive combined primary torsional fracture of the radius and ulna. This postulated fracture undoubtedly exists and should be sought for.

secondary to the torque. Similarly, the distal fragment of the radius is angulated dorsally and ulnarly in the operation of by-passing neo-arthrosis in congenital radio-ulnar synosteosis (Fig. 12). The radius is not angulated ulnarward if length equivalence between the ulna and radius is maintained (Fig. 13).

2. *The radius is twisted non-axially, but the ulna is twisted axially at about the level of the radial fracture.* This situation is induced operatively by osteoclasis of the bones of the forearm in paralytic supination contracture.

3. *The radius is held fixed and the force of torque is expended on the ulna, which is axially twisted and broken spirally.*

In two patients with congenital radio-ulnar synosteosis, the forearm was manipulated into supination after the synosteosis was operatively freed. The ulna broke spirally in its shaft.

Case 2. A man, twenty-two years old, had bilateral congenital proximal synosteosis between the radius and ulna. The synosteosis on the left was released on May 13, 1941, and the proximal third of the radius, including its head, was resected. The stump of the radius was capped with a Vitallium cup. The forearm could not be turned, even after this extensive procedure. Manipulation of the forearm broke the ulna spirally at the juncture of its middle and distal thirds. (This case is presented by the courtesy of Dr. Henry Milch.)

Case 3. A more extensive procedure was carried out in a boy of thirteen with a congenital proximal radio-ulnar synosteosis on the left. The separation of the synosteosis gave supination of only 5 degrees. A segment two centimeters long was resected from the most proximal part of the radius and fascia lata was interposed between the two bones. The inferior radio-ulnar joint was stripped of its ligaments. Ostectomy of the lower part of the radius, apparently to correct bowing of this part of the bone, was done, a piece one-half inch long being removed. Manipulation of the forearm into full supination resulted in a spiral fracture of the upper third of the ulna. (This case is presented by courtesy of Dr. Leo Mayer.)

In forced supination by trauma, a spiral fracture of the neck or the distal third of the ulna takes place if the radius is unable to turn, or a strain of the distal radio-ulnar joint will result, with or without volar luxation of the ulnar head. (This is to be differentiated from the fracture of the ulnar neck which takes place in Colles' fracture. In 800 roentgenograms of broken wrists, Kopasz found the ulnar neck broken twenty-four times.)

The author has seen no example of ulnar fracture by forced pronation of the forearm.

One of the two cases of spiral fracture of the neck of the left ulna caused by such forced supination which the author has seen is described.

Case 4. A man was held up on February 14, 1951, and in the course of the assault sustained a spiral fracture through the neck of the left ulna (Fig. 14). This area was painful and swollen the next day. Supination of the forearm reached 90 degrees and pronation 20 degrees. Rotation of the forearm provoked pain. The forearm was immobilized by plaster in full supination for two weeks. He had no complaints when he was seen on March 13, 1951, but pronation was 0 degrees and supination 75 degrees.

It was believed that he had sustained a forced torsion of the ulna in supination while the forearm was held and twisted by his assailant. The man could not speak English and did not remember the details of the injury.

The forearm should have been pronated to achieve proper reduction rather than supinated which maintained the displacement by torque. The forearm was pronated in the second case example of this fracture. This manoeuvre gave adequate reduction.

4. *The force torques the two bones as if they were one.* The fracture is spiral or not.

When it is not spiral, the two bones are broken at approximately the same level. The radius undergoes non-axial torsion and the ulna undergoes axial torsion. There are two

situations. Either the bones are not angulated at the site of the fracture or they are angulated. Unit torque of the two dorsally angulated bones places the angulated radius volarly and the angulated ulna dorsally. The author has not seen the opposite situation.

A spiral form of fracture is possible when the torque acts on a forearm the radius of which is fixed. A comparable fracture is seen in the leg. The fibula, which is the analogue of the radius, cannot rotate and the force of the torque breaks both bones spirally, the continuity of the line of fracture being interrupted by the interosseous membrane (Fig. 15). Since the force is applied distally, the tibia is broken lower than the fibula. The fixed point of torque must be high (the fixed knee) in such a fracture.

By analogy, a similar fracture may exist in the forearm, although the author has never seen it (Fig. 16). The point of torque would be high. If the point of torque is assumed to be the fixed elbow joint or a point near it, both bones might break spirally, the radius distally and the ulna proximally. The two lines of fracture would run in the same direction and would be collinear, although they would be interrupted by the interosseous membrane. Actually, forced supination of the synosteotic forearm in proximal congenital radio-ulnar synosteosis either results in a spiral fracture of the ulna or dislocates the elbow joint [1].

In either the production or the correction of torsional deformities of the forearm a paired-joint system must be established. This is true both in torsion fractures resulting from accident or manipulation and in torsional osteotomy of the radius for synosteosis of the forearm or contracture. This concept of joint-pairing is therefore of importance in the understanding of torsional fractures. There are four possible forms of joint-pairing in the forearm:

1. Normally, the two radio-ulnar joints pair, giving synchronous motion in each joint about a mechanical axis which runs from the center of the head of the radius to the center of the head of the ulna. Fixation of one joint abolishes motion of the other.

2. After osteotomy of the radius in fixed paralytic supination contracture of the forearm or radial ostectomy in congenital radio-ulnar synosteosis, the mechanical axis of the new paired-joint system, whether it is temporary or permanent, runs from the center of the site of osteotomy of the radius to the center of the ulnar head. The radius angulates ulnarward unless length equivalence between the radius and the ulna is restored by removal of an adequate section of the ulna. The lower the point of torque, the greater is the angulation in dysequivalent length, for the longer ulna thrusts the hand radially.

If both bones are broken at approximately the same level, it is impossible to get cross union in such a way that the distal fragment of the ulna comes into contact with the proximal fragment of the radius and the distal fragment of the radius with the proximal fragment of the ulna. The osteotomized radius twists non-axially and the osteotomized ulna twists axially. This effort was made by Bayer, who, after osteotomizing both bones of the forearm to supinate a forearm held rigidly in pronation by congenital radio-ulnar synosteosis, expected but failed to obtain this cross union.

3. When the ulna is osteotomized and twisted axially with the proximal radio-ulnar joint free, the mechanical axis runs from the center of the head of the radius to the point of torque in the ulna. This operation was devised by Milch [2] to bring the pronated forearm into some supination. He talked of an "*en bloc*" movement of the forearm, but actually a new paired-joint system, albeit temporary, was created. A limited non-union of the ulna is not physiologically disturbing. This took place in one of Milch's cases. Fisher found almost normal rotation of the forearm in a sixteen-year-old boy, who, after a compound fracture of both bones of the forearm at their mid-part, was left with non-union of the ulna. The distal fragment of the ulna was fused proximally to the radius.

4. When both radio-ulnar joints are fixed, rotational osteotomy will succeed only if a paired-joint system is produced. A segment of the radius proximally and a segment of the distal part of the ulna (or the head and neck of the ulna after closure of its epiphysis) are excised.

SECONDARY TORSIONAL DEFORMITY OF THE FOREARM

Secondary torsional deformity of the radius is well described by Evans, whose paper should be consulted by the interested reader.

Roentgenographically, it is easy to distinguish primary torsional fracture from the secondary form. In primary torsional fracture, the fracture line of the radius is spiral and the fragments are separated slightly. The radius is angulated ulnarly. There is no cross-sectional incongruence, since the line of break is not transverse. The fracture of the ulna is likewise spiral, but, whereas the radius turns non-axially, the ulna can turn only axially. Whether the fracture is recent or old, torsion is recognized by the change in relation between intrinsic bony landmarks. In secondary torsional fracture, the fracture line is not spiral. There is cross-sectional incongruence and change in the relation between intrinsic bony landmarks. The degree of ulnar angulation of the radius is less, for less of a cone is swept out.

The ultimate effect of torsion is a lack of full rotation of the forearm. The angulated radius may strike the ulna during rotation, producing a mechanical block. The angulated and torqued radius disturbs the synchrony of the arc of movement of the paired joints. If the upper fragment is assumed to be in almost full supination and the lower in partial pronation, the limit of full supination is soon reached and only the stretching of the proximal radio-ulnar joint can give more supination.

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TRAUMATIC SUBCUTANEOUS RUPTURE OF THE TIBIALIS ANTERIOR TENDON*

BY MERRILL C. MENSOR, M.D., AND GEORGE L. ORDWAY, M.D., SAN FRANCISCO, CALIFORNIA

A review of the literature through 1952 reveals only ten cases of subcutaneous rupture of the tibialis anterior tendon. Because of the rarity of recorded cases in the American literature, it was deemed instructive to discuss the nature of the entity and to add two cases in which surgical treatment was successful.

As stated by Bunnell and by McMaster, a normal musculotendinous mechanism may rupture in one of four locations. In order of frequency these are: (1) the insertion (by rupture of the tendon fibers or avulsion of a fragment of bone); (2) the musculotendinous juncture; (3) the muscle belly; and (4) the origin (in which rupture is rare). The force and leverage required are considerable, with a large safety factor above the coordinated muscle effort of the individual. In sharp contrast to this, a tendon showing pathological changes may be ruptured following even slight trauma. This has been graphically demonstrated by Meyer on the shoulder joint and has been repeatedly observed by nearly all orthopaedic surgeons.

Burman believed that there was some evidence that the normal anterior tibial tendon could rupture in its substance, but subsequent work has presented sufficient histological and clinical evidence to make this statement doubtful.

In the cases available for review, the patients were all males between forty-six and sixty-nine years, with an average of fifty years, except for one case of severe trauma in a worker twenty-five years old reported by Els. This patient's foot had been caught between cars, with a concomitant bone injury.

The trauma may be severe to mild, tending to minimal in the older patients. In two of the reported cases, pathological reports confirmed the suspicion of antecedent degenerative changes. In two cases there was evidence of previous injury to the same area before rupture. In those cases showing incomplete loss of tendon continuity, due either to previous injury or to degenerative changes, the final rupture may be preceded by several transient episodes of pain in the region of the involved tendon, followed ultimately by a snapping sensation and pain indicating complete rupture. A similar history has been obtained, not infrequently, in injuries to the tendo achillis and demonstrates that with continued activity, optimum regenerative powers for satisfactory union do not develop in an injured tendon. The majority of the cases reported followed a fall or twisting injury in which there was sharp plantar flexion of the foot. The most common mechanism is one in which the patient catches his heel on some object and slides down with the foot in plantar flexion.

The trauma is associated with a sharp pain over the front of the ankle and foot, accompanied by a snapping sensation. Inability to maintain weight-bearing is immediate because of pain and a feeling of weakness in the foot. The patient may recover sufficiently within half an hour to walk, but notices a lack of coordination, a variable "slapping" of his foot, or a tendency to stub his toes. In the average patient, the adjustment to the injury is progressive, so that within a relatively short time he may be able to carry on ordinary activity with little obvious handicap. This is in marked contrast to the severe disability in cases of poliomyelitis with paralysis of the anterior tibial muscle. In this disease, it is the exception rather than the rule to find an isolated paralysis of a single muscle, while in traumatic rupture in an otherwise normal leg, the compensatory action of the remaining extensors and peroneals restores a fair grade of equilibrium.

On physical examination, complete rupture reveals a defect, which is both visible

* Presented before the Western Orthopedic Association, Coronado, California, October 16, 1952.

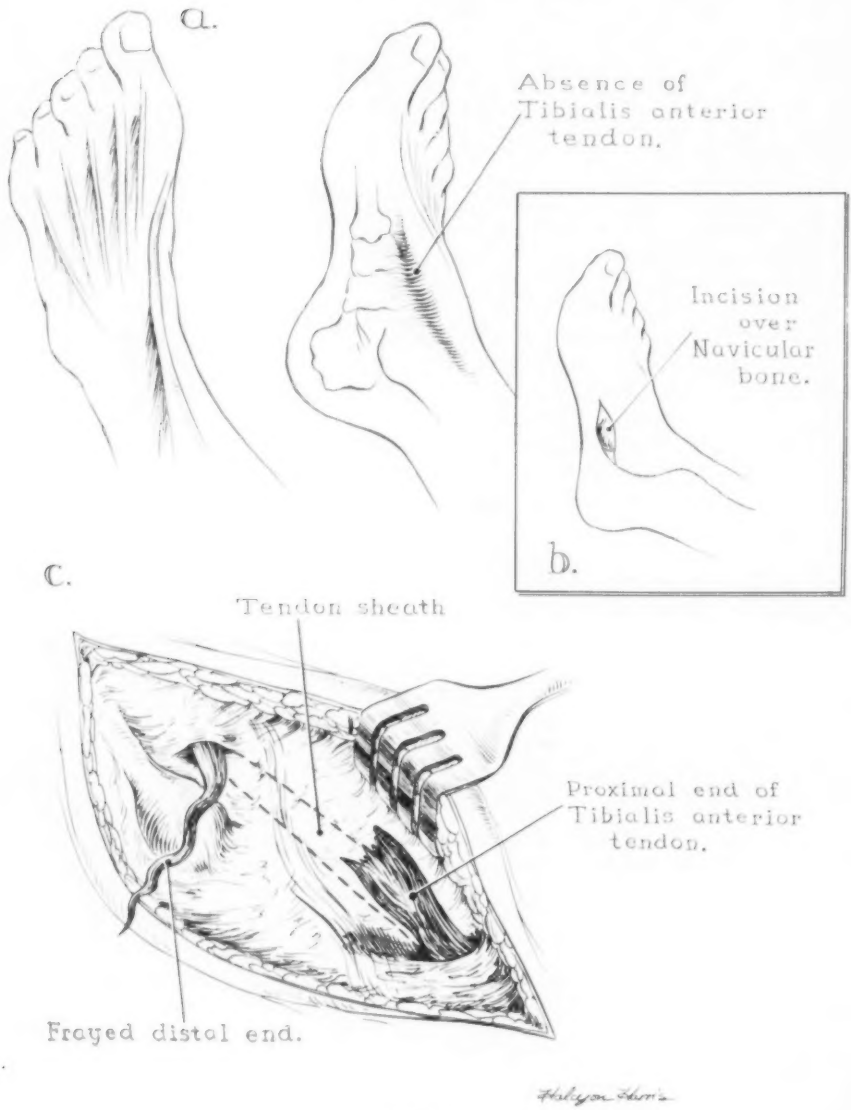

FIG. 1-A

Schematic drawing demonstrating the absence of the tibialis anterior tendon, surgical approach, and pathological findings in Case 1.

and palpable, between the annular ligament and the insertion of the tibialis anterior tendon. The proximal end may be felt as a bulbous enlargement above or below the annular ligament. In recent injuries, the usual ecchymoses and tenderness over the site of rupture are present. The patient complains of weakness of the foot and some limitation of dorsiflexion and his gait demonstrates a variable degree of foot-drop.

In the chronic cases, the range of dorsiflexion may be reduced by 10 or 15 degrees from the patient's normal range. The degree of defect and disability may be evident, especially when the patient is asked to walk on his heels.

Of the ten cases reported to date only four were subjected to surgery; this again

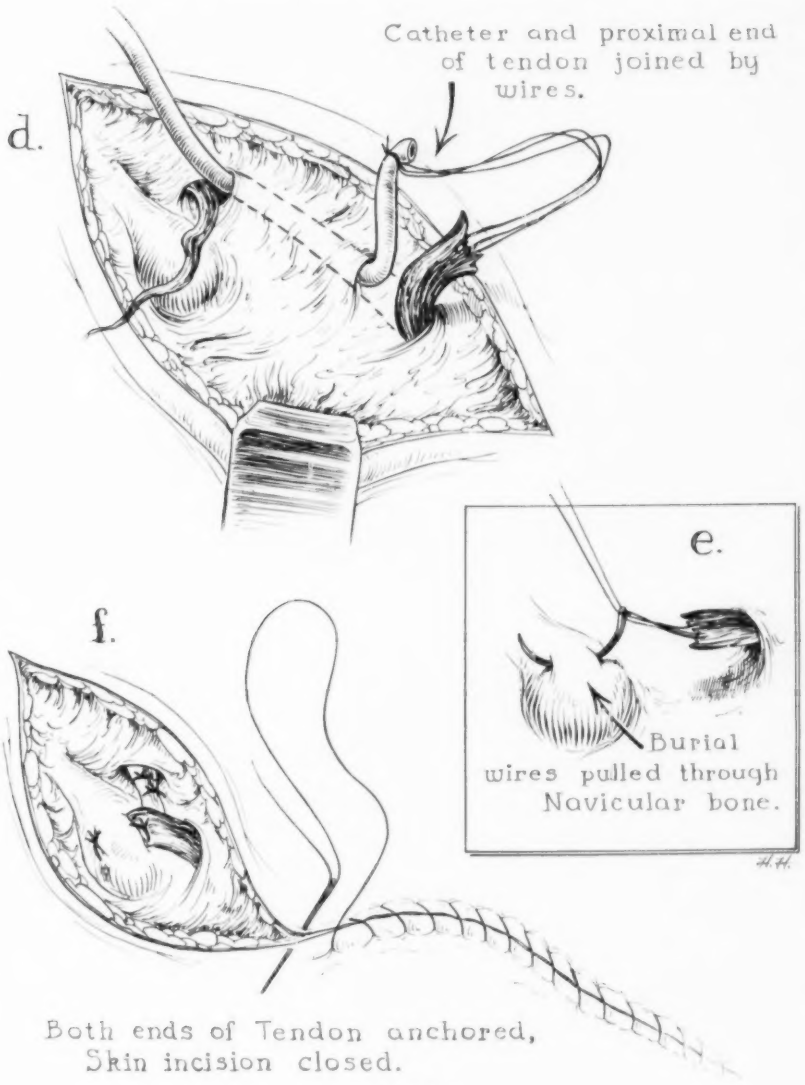
Catheter and proximal end of tendon joined by wires.
d.
e.
Burial wires pulled through Navicular bone.
f.
Both ends of Tendon anchored, Skin incision closed.

FIG. 1-B

Schematic drawing demonstrating the method of repair of ruptured tendon in Case 1.

illustrates the accommodation to the injury developed. Conservative treatment has been successful but not complete, especially in cases in which the recognition of the injury was late and the patient was elderly. However, in those patients who responded well to treatment without surgical intervention, there is the possibility that the rupture had been incomplete. One of the patients operated upon by Lapidus was in this category and might have obtained a good functional result under conservative treatment.

It seems definite, however, that operative repair is the procedure of choice in younger and middle-aged patients with complete tears. This surgery requires sufficient exposure along the course of the tendon to secure the proximal end, mobilize it, and approximate it to the distal portion. Exposure from the annular ligament to the insertion is usually suf-

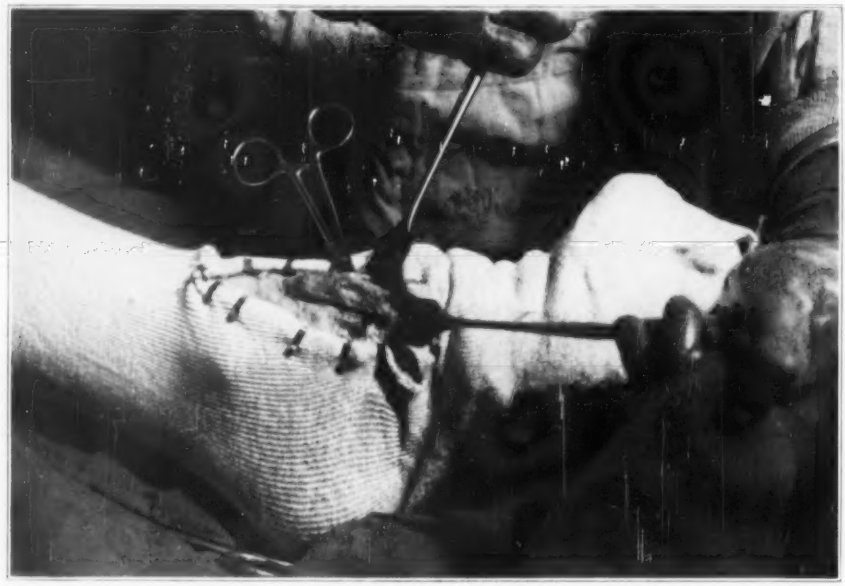

FIG. 2-A

FIG. 2-B

Fig. 2-A: February 6, 1952. Photograph showing ruptured tibialis anterior and character of pathological changes of proximal portion in Case 2.

Fig. 2-B: April 11, 1952. Photograph showing the end result in Case 2, with restoration of motor power of the tibialis anterior.

ficient; this was true in the reported cases and in the authors'. However, in both of the authors' cases, it was necessary partially to incise the dorsum of the tendon tunnel beneath the annular ligament, in order to restore a free gliding mechanism. If the tear is found at or near the insertion, the tendon should be fixed to bone as close to its original insertion as possible. If there is a considerable gap, tendon-grafting may be performed by substituting the extensor of the fifth toe or the proximal portion of the tibialis anterior tendon; the latter is split, starting near the muscle belly, and used as a graft. Moberg suggests that in chronic cases, when a marked degree of muscle contracture has developed as a result of prolonged retraction, the diastasis can be bridged by use of the tendon of the extensor hallucis longus; the stump of the proximal portion of the tibialis anterior is sutured to this tendon, which is sectioned with sufficient length to allow it to be brought through the annular ligament and attached to the distal fragment of the tibialis anterior or its insertion. The distal portion of the extensor hallucis is then inserted to the long extensor of the second toe.

In the two cases of recent injury reported here, repair was easily accomplished in both patients without tendon graft or transfer. In the first case reinsertion of the proximal tendon by a "trap-door" procedure was possible; stainless-steel wire was used. In the

TABLE I

SUMMARY OF REPORTS OF TEARS OF ANTERIOR TIBIAL TENDONS

Author	Age	Injury	Treatment	Remarks
Brüning	45	Twisted foot	Operation	Seen one year after injury.
Els	25	Caught foot in train accident	Heat, massage, and foot support	Associated fracture.
Burman	69	Twisted foot in fall	Rest	Seen one year after injury.
Burman	48	Kicked object	Suture	
Lapidus	46	Twisted foot	Tendon-grafting	
Lapidus	46	Slipped on stairs	Tendon-grafting	Not recognized immediately. Histological examination.
Moberg	50	Fall	Conservative	Seen 7 weeks after injury
Moberg	46	Blow from iron girder	Cast	Associated metatarsal fracture. Seen 8 years after injury.
Moberg	46	Fall	Suture	Seen one month after injury.
Moberg	62	Fall	Suture	Histological examination.
Mensor and Ordway	59	Caught foot and fell backward	Suture	Seen 6 days after injury.
Mensor and Ordway	54	Twisted foot on steps	Suture	Seen 2 weeks after injury.

second case, continuity was restored by stainless-steel wire according to the Bunnell technique. The use of stainless-steel wire instead of silk, in our opinion, minimizes the tendon reaction and avoids the possibility of a draining sinus as reported in the case of Lapidus. The leg is placed in a cast for three weeks, after which assisted active motion, followed by active use two weeks later, is carried out. The majority of patients show recovery of good function in two months and complete recovery within six months.

REPORT OF CASES

CASE 1. Mr. J. F., a white American longshoreman, fifty-nine years old, was in good health and without history of previous injury until November 6, 1951. On this date he was lifting, caught his foot in a pipe, and fell backward. The foot was thrown in full plantar flexion and he felt a sharp pain around the ankle. Walking was painful and he began to walk with a flat-foot gait. He reported to the authors two days later, when the findings typical of a rupture of the anterior tibial tendon were noted. He was hospitalized and operated upon on November 12, 1951.

A curved incision was made longitudinally over the metatarsocuneiform articulation and the distal course of the anterior tibial tendon. The insertion was found to be completely intact for about 1.5 inches. On further exploration, the proximal end of the tendon was found at the level of the malleoli within the tendon sheath. The end was frayed and ecchymotic within the sheath. The sheath was opened, a stainless-steel wire was placed in the torn end by the Bunnell method, and the end was threaded through the vacated sheath and drawn through. The tendon was then fastened to the distal end of the navicular bone with the wire, after a trap door had been made in the bone with an osteotome. After the frayed distal end of the tendon had been plicated to the adjacent fascia and ligament, the wound was closed and the leg was immobilized in a plaster cast, in a position of inversion and dorsiflexion, for three weeks. At this time daily rehabilitation exercises were begun, the leg being kept in the bivalved cast between exercises for two weeks. After that time active use of the foot was begun with the aid of crutches. By the end of two months the patient was walking well and by the end of three months he was able to return to his regular employment without evidence of disability.

CASE 2. Mr. H. R., a white American, fifty-four years old, was standing on the edge of the steps of a hotel on January 15, 1952, intending to walk down the next step backward. He lost his balance, missed his footing, and twisted. In so doing, he felt a sudden sharp pain from the ankle up the lateral aspect of his leg near the shin bone. This was followed by pain, slight swelling, and inability to walk in a normal manner. The pain and swelling subsided in two weeks, at which time he was referred to the authors. He still complained of instability in walking. On physical examination he disclosed a typical steppage gait on the left and evidence of foot-drop. The normal contour of the anterior tibial tendon was absent. There was a bulge above the region of the transverse crural ligament. He was unable to dorsiflex and invert his foot. Surgery was advised.

A repair of the tendon was performed on February 6, 1952. A curved incision was made distally over the course of the anterior tendon from the cruciate ligament to the insertion. A large granulating mass along the course of the tendon was noted and was found to consist of pseudotendon. The tear, about one inch from the insertion, had been complete. After removal of the pseudotendon, the torn ends were approximated and a repair of the tear was made by means of the Bunnell technique, stainless-steel wire No. 34 being used. The leg was immobilized in a plaster cast, with the foot at a right angle and in slight inversion. The cast was bivalved three weeks later and daily active assisted exercises were started. At the end of six weeks, active use of the foot with the aid of crutches was permitted, followed in two weeks by free weight-bearing. At the last examination, six months after surgery, there were no subjective complaints and full function and power had been restored to the foot and ankle.

CONCLUSIONS

Rupture of the tibialis anterior may occur in any portion of the tendon. The problem of the contributory effect of atresia, degenerative changes, or both, has not yet been solved.

Primary operative suture, preferably with stainless-steel wire, is the treatment of choice. Recovery is prompt with little, if any, measurable permanent disability.

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DISCUSSION

The Use of Hyaluronidase in Orthopaedic Surgery

(*Continued from page 608*)

myositis ossificans by this method in soft-tissue hemorrhage in muscle-fiber tears should await further experience or collection of cases. This may be of help, but more specific cases are necessary. The usefulness of this material in the care of hemophilia, as reported by the authors, is remarkable and will be of great value. The authors have shown us an interesting and useful drug; they have reported specific cases illustrating its use in orthopaedic practice. I congratulate them on this interesting and worth-while report.

Dr. J. Albert Key, St. Louis, Missouri: Putting novocain in sprains may work for some, but it did not in the patients upon whom I have tried it. It did not hasten the healing of the sprain and it made the patients a lot less comfortable. I do not like to inject anything, if I can avoid it, into a traumatized area, although it is true that one does not often get an infection. Apparently the authors have had no difficulty with infection following the injection.

I have never had any difficulty in getting novocain to the place where I want it in reducing fractures. It may be, however, that hyaluronidase will make the local anaesthetic more efficient. We like novocain for fractures, but at the same time we do not get as good results, we think, as we do with the general anaesthetic.

Postoperative bleeding and hemophilia make a dispersal agent desirable, but I would like to know whether or not it tends to encourage this bleeding. What is needed in these conditions is something that will stop the bleeding, rather than something that will disperse the blood already there. Does hyaluronidase tend to increase it?

(*Continued on page 684*)

PARTIAL REFLECTION OF THE PECTORALIS MAJOR

An Operation to Increase the Relative Length of Short Above-the-Elbow Stumps*

By Robert Mazet, Jr., M.D., Veterans Administration

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The soundness of the dictum "save all possible length" in amputations of the upper extremity is nowhere more forcefully demonstrated than in the fitting of a short above-the-elbow stump. A short above-the-elbow stump has been defined by the Artificial Limbs Research Project of the University of California, Los Angeles, as one in which between 50 per cent. and 30 per cent. of the humeral length remains (Fig. 1). If less than 30 per cent. remains, the leverage retained by the short humerus is usually insufficient to operate an above-the-elbow prosthesis. These short stumps must, therefore, be fitted with a shoulder-disarticulation prosthesis.

The functional difference between the two types of prostheses to the wearer is relatively great. A shoulder-disarticulation prosthesis permits only limited shoulder-girdle motion (less than the amount possible with an arthrodesed shoulder) and partial scapulohumeral flexion of the device without abduction or rotation. The above-the-elbow prosthesis permits a full range of scapulothoracic motion, and a varying amount of scapulohumeral motion, depending on stump length and strength. The wearer of an above-the-elbow prosthesis regains a much larger proportion of his lost function.

It has been found that an adaptation of the tenotomy in the elbow and antecubital regions described by Blair and Morris results in a relative increase in stump length. The raising of the axillary fold increases the length of the stump which can be included within the socket, as well as the length and power of the humeral lever. The consequent increase in length will, in some borderline cases, permit the patient to operate an above-the-elbow prosthesis. The increase of stump length is obtained by detaching the distal half of the insertion of the pectoralis major tendon from the humerus and folding it back on itself. An increase of an inch in relative stump length is readily attained. The operation has been performed on three arms in two patients. In each instance an above-the-elbow prosthesis was fitted instead of a shoulder-disarticulation type; the patient was thus provided with the increased function concomitant with the preferred prosthetic device.

The Campbell Modulus

A rule-of-thumb guide which is helpful in determining whether an amputee with a short above-the-elbow stump should be fitted with an above-the-elbow or a shoulder-disarticulation prosthesis has been developed by the Artificial Limbs Research Project. This has been designated the Campbell modulus.[1] It is an expression of the relationship of stump length to anteroposterior diameter at the axilla. When the length is 1.33 (or more) times the diameter, a short above-the-elbow prosthesis will, in most instances, prove functionally satisfactory (Fig. 1).

$$\frac{\text{Humeral length from the axilla to the end}}{\text{Anteroposterior stump diameter at the axilla}} = \frac{1.33}{1}$$

This is not an absolute equation. In the cases reported, the relationships were nearly $\frac{1}{1}$. It is, however, a good rough guide for the type of prosthetic fitting to be used.

* Read at the Annual Meeting of the Western Orthopedic Association, Coronado, California, October 18, 1952.

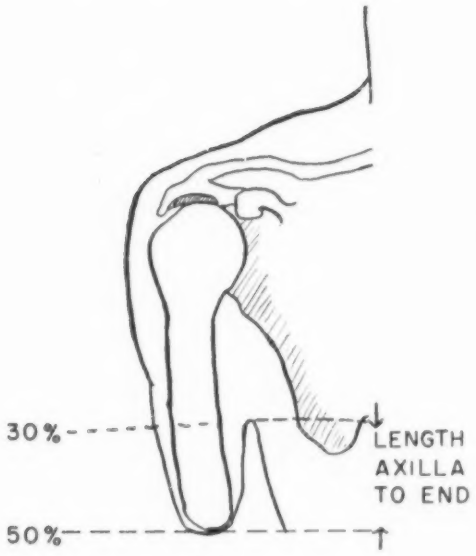

FIG. 1

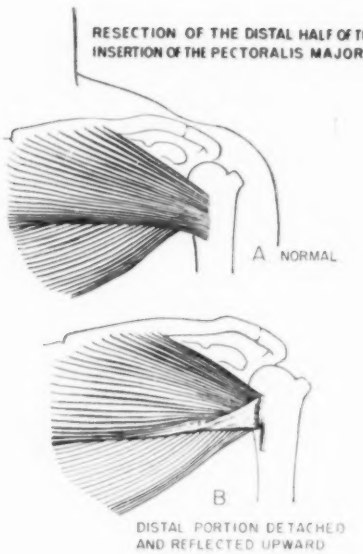

FIG. 2

OPERATIVE TECHNIQUE

The operation is done under local anaesthesia. A two-inch linear incision is made over the deltopectoral groove at the level of the insertion of the pectoralis major tendon. The deep fascia between the two muscles is divided. The deltoid and the cephalic vein are retracted laterally. The pectoralis insertion is exposed, and a clamp is placed behind it to prevent the cutting of the structures beneath. The distal half of the tendon is then freed from its humeral insertion. This is folded up onto the proximal half and is attached to it by interrupted chromic sutures (Fig. 2). The subcutaneous tissue and skin are closed in layers, and a small rubber dam drain is placed in the wound for forty-eight hours. A figure-of-eight dressing is applied with the stump abducted. Stump shrinkage is maintained. Exercises are resumed after three weeks.

FIG. 3-A

FIG. 3-B

Fig. 3-A: Case 1. Photograph shows the somewhat flabby stump before operation.

Fig. 3-B: Photograph shows firmer stump—the result of exercising. The operative scar is just medial to the axillary fold.

CASE 1. A man, sixty years old, who, as a result of a railroad accident, had been subjected, eleven years before, to a shoulder disarticulation on the right and a short above-the-elbow amputation on the left, presented himself, requesting prosthetic fitting. He had never worn prostheses. A fibular intramedullary graft had been introduced into the very short humeral stump to increase its length. He had always had pain on the medial aspect of the stump at the juncture of the graft and humerus. Tenderness was elicited at the palpable step between the two bones. Phantom pain had persisted at intervals. The length from axilla to the end of bone was two and a quarter inches. Shoulder motion was unimpaired.

Partial reflection of the pectoralis major was performed on

May 15, 1952. The wound healed readily, but stump and phantom pains were greatly increased after the operation. Because of this, prosthetic fitting was delayed for a series of local procaine injections and stellate-ganglion blocks. The postoperative stump length was three and a half inches, a gain of one and a quarter inches (Fig. 3-B). Fitting was finally accomplished on August 15, and prosthetic training was instituted. Because of persistent stump pain and phantom pain, the patient was treated at the Pain Clinic at the University of California. Some relief was obtained. Several subsequent adjustments of the socket have been necessary because of continued tenderness at the juncture of the graft and the humerus. Because this restricts the range of motion of the prosthesis, abduction is limited to 25 degrees. However, he is using an above-the-elbow prosthesis.

CASE 2. A rancher, thirty-two years old, became entangled in a hay bailer eight months prior to admission. Immediate bilateral mid-arm amputation had been performed. The left stump had healed *per primam*. On the right, a split-thickness skin graft had been necessary over the anterior aspect of the distal portion of the stump. There had been no infection, but an area, one-half of an inch in greatest diameter, at the proximal end of the graft had failed to epithelialize. He had had no stump-shrinkage or shoulder-mobilization exercises. Gradually lessening phantom pains occurred in both hands. Shoulder-girdle motion was unrestricted. Scapulohumeral motion was approximately one-third of the normal amount. The stumps were flabby and oedematous. Stump measurements were: length from acromion, six inches on the right and seven inches on the left; length from axilla, two inches on the right and two and a quarter inches on the left.

Four weeks after admission the skin defect on the right stump was closed surgically. Three months after admission he had sufficiently increased the range of shoulder motion, and shrunken the stumps, to have the insertion of the pectoralis major folded back on the left. The skin on the right was not yet ready to tolerate the trauma of wearing a prosthesis. The operation on the left was done on February 26, 1952, and on the right on April 11, 1952. The critical measurements (the length from the axilla) following the operation were three inches on the right and three and a quarter inches on the left. A relative increase of stump length of one inch was gained

FIG. 4-A

Fig. 4-B

FIG. 4-C

Figs. 4-A and 4-B: Case 2. Stumps before and after surgery are shown. Note operative scar and the change in facial expression.

Fig. 4-C: Patient demonstrates active abduction in short above-the-elbow prostheses.

for each extremity (Fig. 4-B). He received the left prosthesis on April 15, and the right on May 15, almost five weeks after the second operation (Fig. 4-C). In these, he could abduct the right arm 30 degrees and the left 45 degrees, flex the right arm 30 degrees, and the left 40 degrees.

COMMENT

One patient has been observed in whom motion of the short stump is limited by contracture of the pectoralis major and the latissimus dorsi. Partial resection of the insertion of both tendons in this instance would be beneficial. It is hoped that he may be persuaded to submit to this.

The advisability of shifting the insertion of the pectoralis major proximally at the time of amputation in instances where it is evident that approximately only 30 per cent. of the humeral length will be saved has been considered.

SUMMARY

The simple operative procedure to increase the relative length of the stump in short above-the-elbow amputations involves no risk to the patient. It has permitted the fitting of the more functional above-the-elbow prosthetic device, rather than the less desirable shoulder-disarticulation mechanism, in three arms by an increase in the efficiency of the humeral lever and the amount of stump tissue which can be included within the socket.

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DISCUSSION

The Use of Hyaluronidase in Orthopaedic Surgery

(*Continued from page 680*)

Dr. MacAusland (closing): In regard to the sprained ankle, the severe sprain we still treat in plaster. However, in the minor sprains, we believe that the physiological action of restoration of the pump action of the muscles plus the action of hyaluronidase will hasten the dispersion of the hematoma and restore the minor ligamentous tear to a more normal condition and thus promote a more rapid healing.

In regard to Dr. Schlesinger's remark, we have not used hyaluronidase in the presence of infection for the simple reason that, when we embarked on this program, we were terribly cautious and we felt that there was also the possibility of spreading a local infection and turning a local abscess into a diffuse cellulitis. This has not been proved. Other people have used it in infections; we have not. Perhaps we will soon. We have been very cautious, as it is a new drug and we do not wish to make any mistakes.

We have had no infections following injections into the joints for hemophilia or acute hemarthrosis. However, in regard to hemophilia, we would like to bring out one definite point. The hyaluronidase will not stop the bleeding if it is present. We rely on lowering the venous clotting time with fresh blood or lipolized plasma.

Hyaluronidase in the treatment of fractures, particularly of the wrist, in our hands has been a very definite adjunct, because it gets rid of the oedema locally. We don't claim that our results in Colles' fractures are any better, but we feel that we can get an adequate reduction easier, because we can palpate the bone ends. In other words, we inject the hyaluronidase at the fracture site, we apply an elastic bandage for the pressure factor, and we wait four or five minutes. Then the hematoma has dispersed and a very exact palpation at the fracture site is possible. The girth of the circumference of the broken wrist is practically normal, and the bone ends may be palpated very easily. We think it is a very definite aid in the reduction of the fracture.

OSTEITIS PUBIS OF TRAUMATIC ETIOLOGY

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Scanty attention has been shown to the entity osteitis pubis by orthopaedic surgeons over the past twenty-five years, as attested by the few articles appearing in the orthopaedic literature. Since 1934, only four papers have been written and but five cases presented (Burman, Weinkle, and Langsam in 1934, Silver in 1941, Powell in 1947, and Friedenberg in 1950). The urological literature, however, abounds with case descriptions and theories concerning the etiology and pathology of osteitis pubis. Beach hails the entity as "an orthopedic disease sponsored by urologic surgery". Kirz estimates that osteitis pubis develops in 3 per cent. of patients undergoing suprapubic operations.

A young male patient with osteitis pubis of what was apparently traumatic origin was recently studied in the Orthopaedic Surgery Department of the University of Illinois Hospitals. The uniqueness of the clinical course and pathological findings and the review of four other very similar cases in the literature suggested that an entity similar to postoperative osteitis pubis in the elderly male may also occur in the younger age group. The need for a more thorough examination of this disease became apparent.

The majority of cases of postoperative osteitis pubis occur as complications of suprapubic prostatectomy. The disorder may not manifest itself until several months after surgery, when the patient presents himself with the complaint of severe pain over the symphysis with lower abdominal and adductor radiation. Thickening of the tissues over the symphysis, with localized tenderness, is usually present. Severe adductor spasm is pronounced. Inguinal lymphadenopathy may occur.

Although genito-urinary surgeons hold numerous theories of the etiology and pathology, a review of the literature to date has disclosed only eight cases of osteitis pubis after prostatectomy in which pathological descriptions have been based on biopsy. Silver, in 1941, presented the first two of these, with reports of chronic inflammation in one and nonspecific acute inflammation in the other. In 1945, Muschat reported that curettings showed subacute osteomyelitis. Beach, in biopsies of two patients in 1949, found a panosteitis microscopically. In 1951, Lavalle and Hamm described three cases in which tissue showed fibrosis and subacute and chronic inflammation involving the periosteum, bone, and cartilage. (*Pseudomonas aeruginosa* was cultured from all three of these patients, as well as *Proteus vulgaris* from one.) Lavalle and Hamm felt that they had conclusively shown that the complication of osteitis pubis is a chronic inflammatory disease of bone, cartilage, and periosteum of the pelvic girdle and that it is of bacterial origin. Their view is strongly supported by the facts that (1) in each of the reported instances in which a culture was taken a growth of bacteria was obtained [3, 8, 10, 12] and that (2) in each of the eight reported patients on whom biopsy was performed the pathological finding was that of inflammation.

ROENTGENOGRAPHIC CHANGES

Roentgenographic Appearance of Normal Symphysis

Todd [13], in 1923, added the symphysis to the other indicators of skeletal age and noted its peculiarities in formation and growth. From the roentgenographic standpoint, he further observed [14] that in childhood and adolescence the contiguous faces of the symphysis have no definite outline, but present the undulating or billowy surface which is characteristic of a diaphysis under the epiphyseal cartilage. He noted that activity in this bony face is heralded at about twenty years by disintegration of the billowy surface and osteoporosis of quite marked extent in the region where the symphysial face and the ventral

aspect of the pubic bone meet. About the twenty-third year the progressive obliteration of furrows on the symphysial face is accompanied by increasing definition of a superior margin which appears to be directly formed on the diaphysis or body of the bone itself, and not through the intermediary of an ossified epiphysis. The superior margin is completed about the end of the twenty-sixth year, according to Todd[14].

Burman, Weinkle, and Langsam, in reviewing 127 normal roentgenograms through the ages from birth to seventy-nine years, found changes very similar to those described by Todd. They described the adult type of symphysis as being reached in the third decade, when the following features may be seen: "... the symphysis pubis is more or less vertically placed, with straight and sometimes concavo-convex edges. It is narrow, its width being about one-eighth of an inch. Some sclerosis of the edges is noted, indicating increasing ossification of the cartilage face. Mammilation, or grooving, is no longer seen."

These findings persist through the age of forty-five. From then until the age of sixty, the typical configuration of the symphysis is still unaltered, but its edges may be more sclerotic and its width less than one-eighth inch. Arthritic spurring may be seen superiorly during this age interval. From sixty to seventy-five years, according to Burman and his associates, increased lipping, narrowing, and sclerosis may be noted.

Roentgenographic Appearance of Abnormal Symphysis

The changes which occur in the urological patient with postoperative osteitis pubis several weeks after clinical manifestations are best classified into certain stages, according to Henderson:

> "*Stage* 1. No abnormality or slight fraying of the corners of the symphysis . . .
>
> "*Stage* 2. Definite decalcification of the bodies of the pubes: this may be uniform or patchy . . . and may involve one or both inferior pubic rami.
>
> "*Stage* 3. Decalcification may continue till a U-shaped defect is seen at the site of the pubic symphysis . . .
>
> "*Stage* 4. Exceptionally the process is associated with sequestrum formation.
>
> "*Stage* 5. Stage of healing. At first there is recalcification with normal trabecular conformation, and eventually marked narrowing or fusion of the symphysis pubis supervenes . . . New subperiosteal bone may be laid down in the region of muscle attachments."

The last stage may require up to two years for completion.

Changes of a similar nature may also be seen concomitantly in the ischial tuberosities, in which case the stage of healing is often accompanied by deposition of subperiosteal bone. In addition to involvement of the pelvic girdle, it is to be emphasized that narrowing of the hip joints, though rare, may sometimes be noted following an attack of osteitis pubis[3, 12].

CASE REPORT

O. R., an eighteen-year-old white male, was admitted in February 1950 with a history of lower mid-abdominal pain with radiation into the upper medial portions of the thighs. The onset had occurred one year previously after he had been running in indoor track at high school. In January 1949, his physician, suspecting appendicitis, removed the patient's appendix. He was asymptomatic during his convalescence, a period of three weeks, but upon resuming physical exertion he experienced a return of discomfort in both adductor regions. The pain troubled him when he attempted to run or when he walked any distance, and a "waddling" gait manifested itself when he became fatigued. He was referred to an orthopaedic surgeon in January 1950. Roentgenograms revealed a destructive lesion in the region of the symphysis pubis. A biopsy was done at that time, and a diagnosis of chondrosarcoma was made. The patient was then referred to the University of Illinois Hospitals for definitive treatment.

The patient's general physical examination showed no unusual findings. His temperature, pulse, and respirations were normal. The orthopaedic examination showed a normal stance and gait. The spine was of normal configuration and demonstrated a complete range of painless motion. The upper extremities were normal in all respects. A well healed right rectus incisional scar was present. There was a recently healed transverse suprapubic surgical incision eight centimeters long. The underlying soft tissues were thickened and somewhat tender. Suggestive bony enlargement of the symphysis pubis, which was tender to palpation,

FIG. 1

M.M. February 25, 1952. Appearance of a normal pelvis in an eighteen-year-old male, showing physiological irregularity and furrowing of the symphysial face.

FIG. 2

O.R. January 3, 1950. Original lesion in patient's symphysis pubis, showing active, spotty destruction with ballooning of the dorsal margin and an irregular central defect 2.4 centimeters in its widest diameter.

was noted. No pain was elicited on compression of the pelvis. Attempts at passive abduction of the hip joints beyond twenty degrees produced severe pain in the adductor groups and the symphysis pubis. Otherwise, the hips showed a full range of passive motion, as did the remainder of the joints of the lower extremities.

FIG. 3

April 25, 1950, one month after operation. The graft was inserted after resection of the symphysis pubis.

FIG. 4

May 12, 1950. Showing the defect present after removal of the graft.

Routine laboratory findings were within normal limits, except for an erythrocyte sedimentation rate (Wintrobe method) of nineteen (slightly elevated) and the presence of an occasional pus cell in the urine.

In March 1950, with a clinical diagnosis of chondritis of the symphysis pubis, a suprapubic resection of this structure was accomplished, the defect being bridged by an autogenous tibial-bone graft. At the time of

FIG. 5

June 22, 1951. Fourteen months after removal of the graft, showing tendency toward spanning of defect.

FIG. 6-A

February 29, 1952. Roentgenogram made twenty-two months after operation shows mobility of symphysis with patient standing on right lower extremity.

surgery, the lesion appeared yellow in color, was firm and gritty in consistency, and contained irregularly arranged bony spicules. The suprapubic wound failed to heal primarily, however, and within ten days gross infection was evident. Hemolytic *Staphylococcus aureus* was cultured repeatedly from the pus. Neither penicillin nor streptomycin controlled the infection, which eventually became contaminated with several

FIG. 6-B

Roentgenogram made on the same day shows motion present with weight borne on left lower extremity.

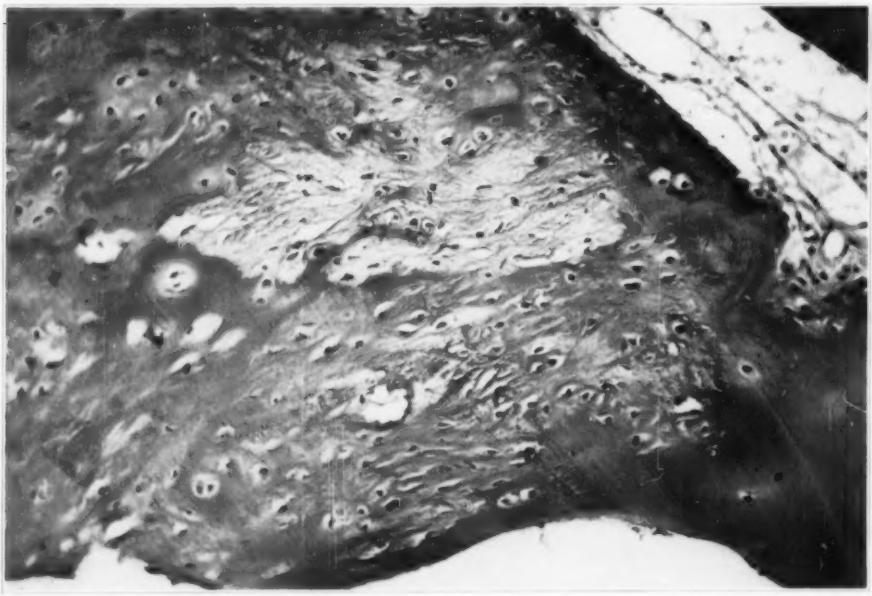

FIG. 7

Photomicrograph (× 200) illustrating degeneration of hyaline cartilage.

secondary organisms. Two months after its insertion, the bone graft and a sinus tract which communicated with the skin were removed surgically and the wound was packed open. Healing then occurred without sinus formation, and the patient was ambulatory six weeks later when he was discharged. He has subsequently returned to full activity, including strenuous sports, without complaint or disability.

FIG. 8

Photomicrograph (× 80) of original biopsy, demonstrating fibrosis of marrow spaces.

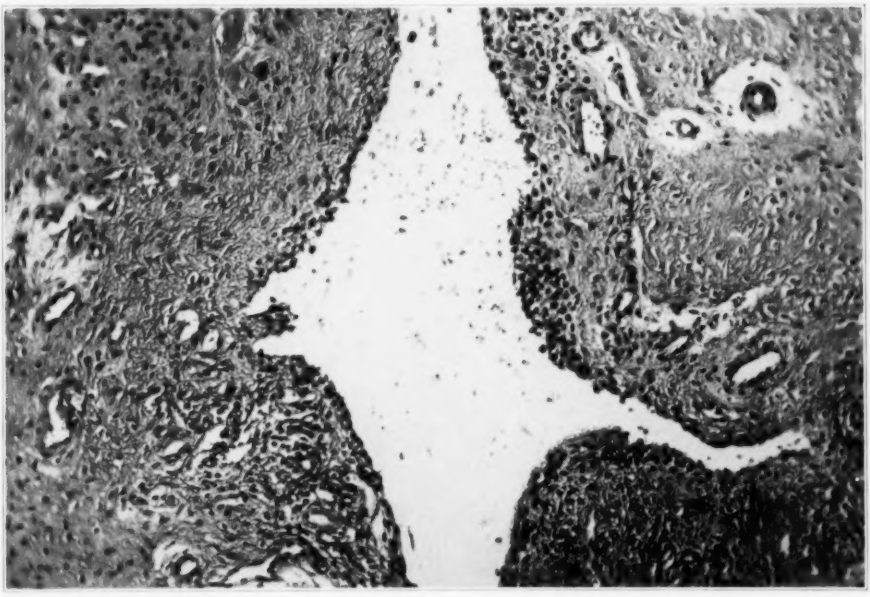

FIG. 9

Photomicrograph (× 145) of synovial cavity, showing diffuse subsynovial infiltration of chronic inflammatory character.

Although fusion of the symphysis would probably have been ideal, further surgery was believed to be unwarranted because of the patient's complete lack of symptoms referable to this joint.

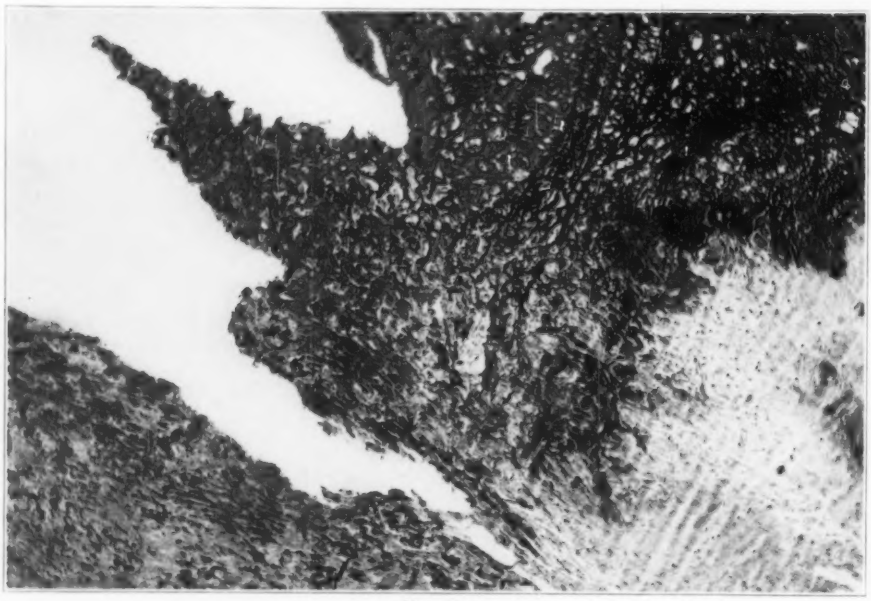

FIG. 10

Photomicrograph (× 75) of fibrinous exudate covering cavity of what was probably the joint space.

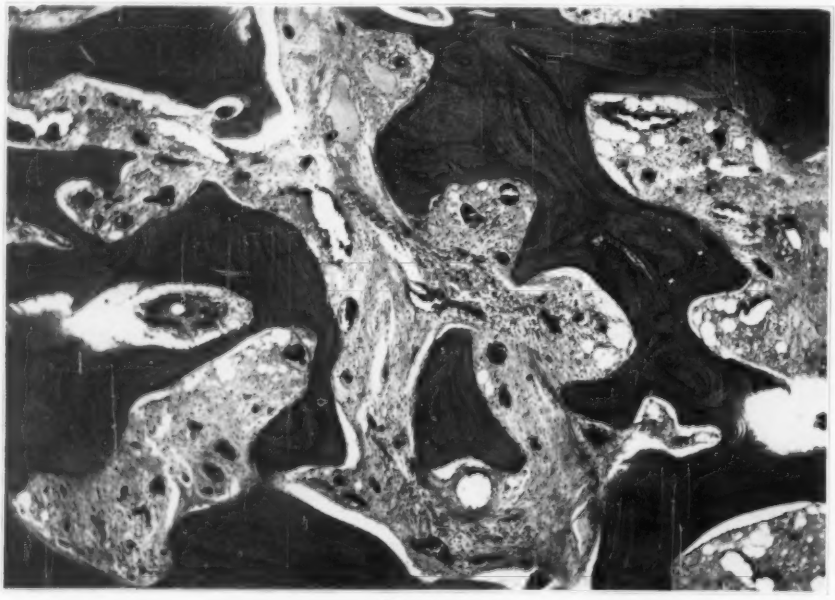

FIG. 11

Photomicrograph (× 35) of final specimen, illustrating more active bone resorption and fibrosis of marrow spaces. Note increased vascularity throughout and collection of chronic inflammatory cells in the center of the photomicrograph.

Examination of the patient's original roentgenograms (Fig. 2) disclosed the typical findings of an advanced stage of osteitis pubis. Mild osteoporosis of the bodies and rami of the pubes was noted. Active, spotty destruction of the symphysial face, with ballooning of its dorsal margin, was present, and there was a large,

irregular, U-shaped defect in the joint space which measured 2.4 centimeters in maximum width. The roentgenogram of the symphysis of a normal eighteen-year-old male is illustrated in Figure 1 for comparison. Figures 3 to 6-B are reproductions of the patient's roentgenograms, showing the manner in which the graft was placed, the appearance after its removal, and the tendency toward spontaneous bridging of the gap, fourteen and twenty-two months postoperatively. Figures 6-A and 6-B reveal the amount of motion present in the symphysial neo-arthrosis at the most recent examination.

The obtaining of a specimen for histological examination from this patient has made possible a description of the pathological changes associated with osteitis pubis of traumatic origin in a young person.

Sections from the blocks of tissue initially removed from the lesion showed fibrous connective tissue, fibrocartilage, and bone. There was evidence of degeneration of hyaline cartilage, fibrosis of the marrow spaces, and a low-grade inflammatory reaction in the connective tissue and synovial membrane (Figs. 7 to 9). The inflammatory reaction was low-grade and diffuse and was characterized by lymphoid, plasma-cell, and mononuclear-cell infiltration. There were no specific features to suggest an etiological factor. There was no evidence of tumor in any part of the sections.

Sections of the entire symphysis pubis removed three months later showed all of the features which had been apparent in the original biopsy material. Here, however, there was a fibrinous exudate undergoing organization, covering the symphysis joint cavity (Fig. 10). Fibrosis of the marrow spaces was somewhat more widespread than in the previous specimen and there was evidence of more active bone resorption than had been previously seen (Fig. 11). Again, no evidence of neoplasm was observed. The pathological diagnosis of the combined specimens was: low-grade inflammation in and about the symphysis pubis, with marked bone resorption and fibrous connective-tissue replacement of the marrow — osteitis pubis.

These findings are suggestive evidence that the traumatic disease involving this patient's symphysis was inflammatory in nature and very possibly bacterial in origin.

OTHER CASES OF TRAUMATIC OSTEITIS PUBIS

The curious resemblance of this patient's disease to that of osteitis pubis in the male after prostatectomy prompted a search of the literature for similar cases. Four were found and in each a definite comparison to the above case could be made. These patients are briefly reviewed in order to emphasize their similarities.

Case 1 (Peirson, 1929): A man, twenty-five years old, whose occupation involved carrying heavy boxes which he supported partly on his lower abdomen, had complained of pubic pain of seven months' duration. He was hospitalized for two weeks and improved, only to experience recurrence of pain several months later. At this time he had a frank suprapubic abscess which was drained of *Staphylococcus aureus* pus.

Peirson ventured the opinion that the case represented one of primary infection of bone, and classified it as a non-tuberculous osteochondritis. It is believed, however, that this case probably represents an osteitis pubis of traumatic origin which remained chronic for seventeen months before culminating in abscess formation.

Case 2 (Painter, 1930): A white woman, twenty-eight years old, had complained of pain in the region of the symphysis, associated with overexertion, for about a year. Roentgenograms revealed a small cavity, which was curetted; no pus was obtained and the diagnosis was inflammation and repair.

Painter presented this as a Brodie's abscess in the symphysis pubis. The presence of enchondral bone formation and the absence of pus, however, are not typical of Brodie's abscess. For this reason, and because of its clinical resemblance, Painter's case may well have been one of traumatic osteitis pubis.

Case 3 (Burman, Weinkle, and Langsam, 1934): A seventeen-year-old white male had sustained trauma to the symphysis pubis when he was crushed between a fence and a slowly moving truck. His initial pain subsided within three weeks, but four and a half months later he had recurrence of pain in the region of the symphysis, radiating into the abdomen, thighs, and groins. He had been rowing the previous few months for the school team. Roentgenograms at this time showed an irregular, woolly destruction of the symphysial face and what appeared to be a few free bone fragments. Treatment was symptomatic and pain abated within three weeks. Roentgenographic follow-up showed gradual filling-in of the defects, which was almost complete in a fifteen-month period.

TABLE I

COMPARISON OF POSTOPERATIVE OSTEITIS PUBIS WITH TRAUMATIC OSTEITIS PUBIS

	Postoperative Osteitis Pubis	Traumatic Osteitis Pubis
Age	Elderly patients.	Young adults.
Sex	Males.	Males and occasionally females.
Clinical picture	Pain and tenderness over pubis with adductor radiation.	Pain and tenderness over pubis with adductor radiation.
Inciting cause	Retropubic surgery.	Trauma to symphysis pubis.
Etiology	Bacterial.	Bacterial.
Pathology	Chronic inflammation.	Chronic inflammation.
Roentgenographic changes	Osteoporosis and cavitation followed by filling-in of the defect.	Osteoporosis and cavitation followed by filling-in of the defect.
Duration	Six to twenty-four months.	Up to twenty-four months.
Complications	Abscess formation; involvement of the hip joints.	Abscess formation.

Burman and his associates recorded this case as an adolescent osteochondritis of the symphysis pubis. The typical course which the disease followed, both clinically and roentgenographically, strongly suggests, however, that this was another case of traumatic osteitis pubis. No pathological proof exists to support either contention.

CASE 4 (Klinefelter, 1950): A sixteen-year-old white male struck his abdomen a hard blow over the symphysis against the hip of an opponent while he was playing basketball. Local pain and tenderness subsided within five days and he resumed his usual physical activities. Three weeks later pain of a moderate boring quality recurred in the symphysial region, which became warm and tender but showed no signs of fluctuation. Roentgenograms at this stage showed demineralization and spotty destruction of the right pubis, most marked about the symphysis, involving the greater portions of both rami and extending into the inferior ramus of the ischium. Three weeks of bed rest resulted in the beginning of gradual pain-free recovery, and the patient resumed his former activities ten weeks after the injury. Roentgenograms at this time showed the region of destroyed bone being replaced by normal bone. New-bone formation proceeded gradually until after two years the symphysis appeared normal.

Klinefelter was undoubtedly correct in reporting his case as one of osteitis pubis, even though he lacked proof by biopsy. The role of trauma as an inciting cause is apparent in this instance.

Striking likenesses are obvious among the five cases presented: (1) They occurred in young adults; (2) trauma was consistently an inciting cause; (3) all had symptoms and signs of typical osteitis pubis; (4) roentgenographic manifestations were characteristic; and (5) the course of the disease was uniformly prolonged in so far as bone healing was concerned. Added similarities in two instances were the presence of *Staphylococcus aureus*, bacteriologically, and the picture of inflammation, pathologically.

It is felt that the similarities in these five cases form an entity which may be termed "traumatic osteitis pubis". This entity in addition bears a close resemblance to the better known osteitis pubis of urological importance. Table I demonstrates this resemblance between cases of osteitis pubis of postoperative origin and those of osteitis pubis of traumatic origin. Examination of Table I points to the fact that these two groups of cases are extremely alike in all but two respects—the age of the patients afflicted and the inciting cause of the disease.

PATHOMECHANICS OF TRAUMATIC OSTEITIS PUBIS

To explain the pathomechanics of osteitis pubis in the younger patient, a study of the pubic bone itself offers a possible solution. Henderson pointed out that the external aspect

of the pubis and the pubo-ischial rami are well covered by muscle attachments, but the internal aspect is not, and a large area is covered by periosteum and parietal pelvic fascia alone. This is the area which is affected in osteitis pubis, and it is obviously less well equipped to withstand extension of infection than an area well covered by muscle. Wilensky stated that the blood supply of the pubic bone arises mainly from a periosteal plexus, but that, compared with other parts of the skeleton, the pubic bone has a very poor blood supply. He notes, however, that in young persons the blood supply is most abundant in and around the centers of ossification, including the symphysis, where the vascular loops are essentially end vessels. Todd has shown [14] that osteoporotic activity with disintegration of the bony face of the symphysis occurs normally at about twenty years; Burman and his co-writers found such changes in a somewhat younger age group.

It may be postulated that trauma, either directly to the symphysis or through tension of the rectus abdominis muscles, causes periosteal and subperiosteal damage to the bone. Injury occurring at a time when the bone structure is physiologically weakened because of normal osteoporotic activity may have an inordinately damaging effect. Thrombo-embolic occlusion of the end vessels of the symphysis may then occur, and a subsequent transient bacteraemia may establish a focus of infection. Local hyperaemia, stimulated by the infection, may then accelerate bone absorption. The ensuing sequence of events of the disease in the young no doubt closely corresponds to that in the elderly. The amount of bone destruction, the degree of extension to other bones or joints, and the occurrence of sequestration or abscess formation all depend upon the virulence of the organism present and the resistance of the host.

TREATMENT

Osteitis pubis of traumatic origin should in general be treated conservatively. Complete bed rest may be necessary in the acute phase and a plaster-of-Paris spica may be required to limit still further hip and pelvic motion in such instances. Later, with improvement, a snugly drawn sacro-iliac belt might be useful to decrease symphysial movement during weight-bearing. Ambulation should be resumed as soon as it can be tolerated, but strenuous activities should be minimized until roentgenographic and clinical signs indicate healing. The administration of antibiotics would probably be of value during the acute phase, especially if signs of gross infection become manifest. When abscess formation occurs, which is rare, incision and drainage should be done, as elsewhere in the body.

CONCLUSIONS

A review of the literature indicates that osteitis pubis is considered by the majority of authors to be an inflammatory disease of bacterial origin which occurs most commonly following retropubic surgery in males.

It is believed that heretofore this disease occurring in young adults of both sexes following trauma to the symphysis pubis may have been overlooked in reporting of cases.

The specific pathological picture of traumatic osteitis pubis has been suggested by virtue of microscopic examination of tissue removed from the patient discussed.

NOTE: Acknowledgment is made to Dr. Granville Bennett for his interpretation of the pathological findings in the case presented.

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POSITIVE PRESSURE IN THE REDUCTION OF FRACTURES OF THE TIBIAL CONDYLES

A Preliminary Report

BY LOUIS SPIGELMAN, M.D., LOS ANGELES, CALIFORNIA

In this article, a method is described of applying positive pressure to plateau fractures of the tibia.

The advantages and importance of maintaining positive pressure or the contact-compression factor have been proved, both theoretically and practically. Key and Charnley both have employed parallel stainless-steel pins and turnbuckles to maintain apposition and pressure in routine knee fusions. They found that this hastened osseous fusion. Eggers used a slotted plate to allow the telescoping of the fragments, with the muscles acting as the compressing force. His experimental work on rats proved the theoretical importance of the contact-compression factor.

In the method to be described, the tension of a simple internal cantilever spring maintains the positive pressure.

The technique of applying positive pressure in the reduction of fractures of the tibial condyles requires (1) a Moore pin, three thirty-seconds of an inch in diameter and five inches in length, and a nut and (2) an orthopaedic drill, pliers, and a mallet. Figures 1-A to 1-D illustrate and explain the procedure.

This technique has been employed in three cases of fractures of the tibial plateau. In the first two, the casts were removed approximately ten days following surgery, at which time the patients were permitted to move the knee freely. The first two patients were both back at work in approximately ten weeks, with an almost complete range of normal motion. Because the method was new, we were rather hesitant to permit earlier weight-bearing. The third case is presented in detail:

T. S., a white male, twenty-three years old, was struck on his right knee on February 4, 1952, by the bumper of a car. He was admitted to the Los Angeles General Hospital shortly after the accident. Roentgenograms revealed a fracture of the lateral condyle of the right knee with approximately one fourth of an inch separation of the fracture fragments (Fig. 3-A).

Blood was aspirated from the joint. A closed reduction was attempted but was unsuccessful. Open reduction was then performed on the same day, and the technique previously described was used (Fig. 3-B). A plaster-of-Paris cast was applied, and, after ten days, the cast and sutures were removed. Active non-weight-bearing exercises were started.

On the twenty-first day after the operation the patient was permitted complete weight-bearing. At that time he had an almost complete range of painless knee motion.

The knee was re-examined and roentgenograms were made on March 27 and on May 12, 1952. The only limitation of motion was a lack of approximately 3 degrees of extension.

On July 12, 1952, the patient was seen for a final follow-up and x-ray examination. The knee was painless and the patient had no complaints. Extension lacked 3 degrees. Flexion was to 140 degrees bilaterally. There was no lateral instability; the drawer sign was negative; there was no atrophy of the thigh or leg; and there was no swelling of the knee.

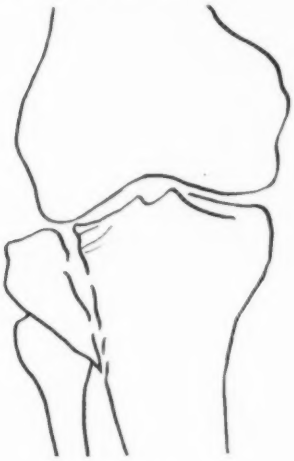

FIG. 1-A

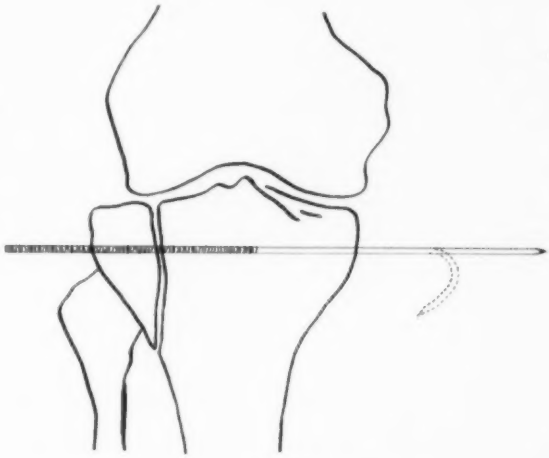

FIG. 1-B

Fig. 1-A: Through a two-inch lateral incision the depressed fragment is elevated.

Fig. 1-B: The threaded wire is drilled through both fragments through a two-inch medial incision. The spear point on the medial aspect of the condyle is bent to a large U.

FIG. 1-C

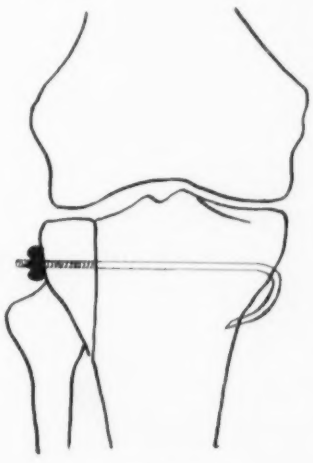

FIG. 1-D

Fig. 1-C: The U portion is driven into the bone with a mallet until the point engages the cortex.

Fig. 1-D: The nut is threaded on the wire and tightened until the spring is under tension. The excess wire is removed and closure is done.

FIG. 2-A

FIG. 2-B

Roentgenograms showing one of the earlier cases.

DISCUSSION

The bolt and nuts employed hitherto in the reduction of plateau fractures could not maintain constant positive pressure[6]. The only tension developed by this method of fixation was due to the elasticity of the material. However, constant positive pressure is

FIG. 3-A

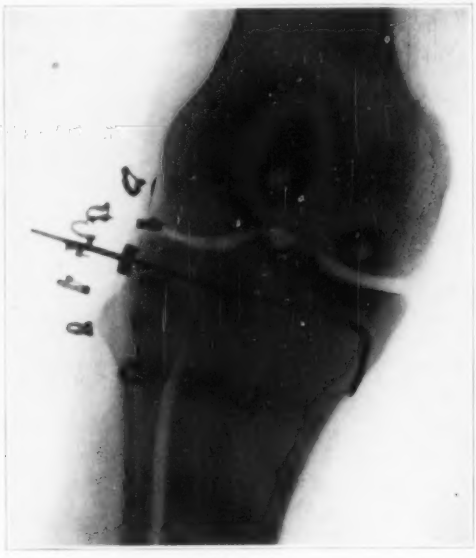

FIG. 3-B

Fig. 3-A: Case 3. February 4, 1952. The patient had sustained a plateau fracture with one fourth of an inch separation of the fragments.

Fig. 3-B: February 4, 1952. There was slight residual separation between the fracture fragments at the joint surface.

FIG. 3-C

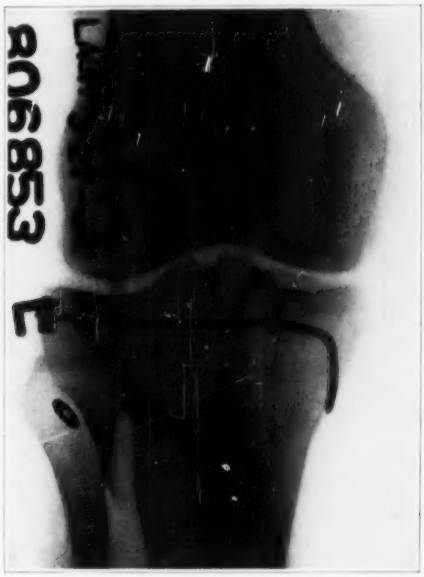

FIG. 3-D

Fig. 3-C: February 21, 1952. The slight separation was taken up by the spring tension.
Fig. 3-D: March 27, 1952. At seven weeks after the operation the proximal side of the fracture line could no longer be visualized. Some callus was noted in the distal portion of the fracture line.

FIG. 3-E
May 12, 1952

FIG. 3-F
July 12, 1952

applied to the fracture fragments by incorporating a cantilever type of spring, such as the U-shaped portion of the pin. The advantages of incorporating a spring can be seen by comparing the tension graphs (Figs. 4-A and 4-B).

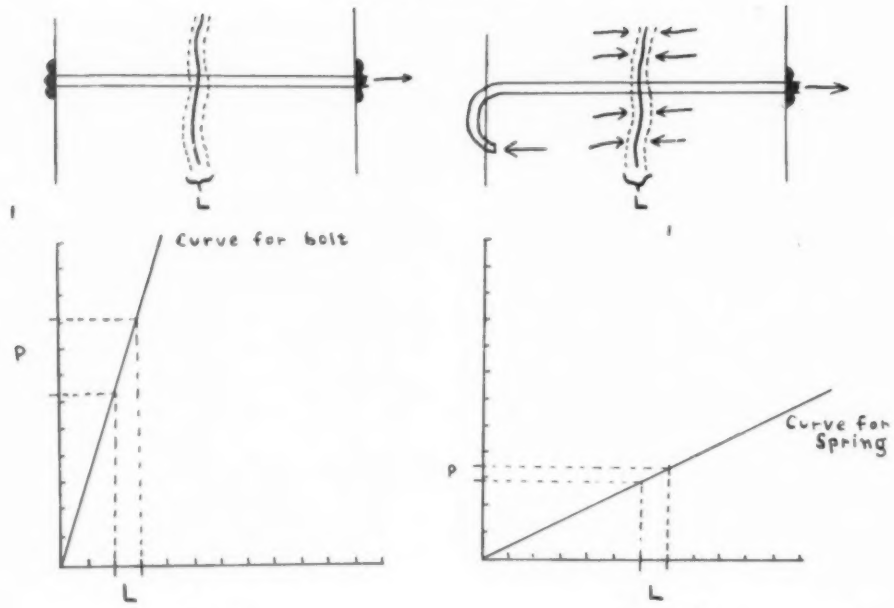

FIG. 4-A

FIG. 4-B

Fig. 4-A: A change of length (L), caused by bone absorption, creates a great drop in tension load (P).
Fig. 4-B: The same change in length (L) causes much less of a drop in tension (P) because of the spring action involved.

There are a number of variables which act to increase or decrease the amount of tension: the length of the U (or spring), the diameter of the wire, the metal employed, and the use of different sizes of washers and nuts. There are variables which cannot be estimated exactly because of the nature and reaction of living tissue.

It is planned to use washers at each end of the pin to prevent the two ends from sinking into the bone.

NOTE: The author wishes to express his thanks to F. R. Shanley, Professor of Engineering, University of California at Los Angeles.

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INTERNAL FIXATION FOR FRACTURES AND DISLOCATIONS OF THE PELVIS*

BY GORDON WHISTON, M.D., CASPER, WYOMING

Internal fixation for certain types of fractures and dislocations of the pelvis is not new or unusual, but a simple method of fixation has been used in several cases, the technique of which apparently has not been previously described in the literature.

Fractures of the Ilium

Of fractures of the pelvis, fracture of the wing of the ilium is one of the most frequent; it is usually due to direct violence or to lateral crushing injuries. Holdsworth classifies[1] pelvic disruption into two types: first, pelvic injury with sacro-iliac dislocation, and second, pelvic injury with fracture of the ilium near the sacro-iliac joint. The first type results in a large percentage of poor end results, only 50 per cent. of the patients returning to heavy work. Many of the sacro-iliac dislocations require an arthrodesis because of persistent pain and disability. Not all fractures of the wing of the ilium are near the sacro-iliac joint and it is those occurring in the anterior third that led to use of the internal fixation to be described.

Treatment

It has been customary to treat iliac-wing fractures by having the patient rest in bed with both hips flexed and a firm bandage fastened about the hips. In one case with this type of fracture, this method failed to give relief from pain, as the fragment moved with each respiration and could not be immobilized by external means. The abdominal oblique muscles, both the internal and the external, originate along the anterior third of the crest of the ilium and are in constant activity during respiration. The need to prevent the resulting motion of the fragment suggested the use of internal fixation. Levine described, in a case report, the use of a curved metal plate fixed in the iliac fossa with screws. This procedure required rather wide exposure of the ilium to allow placement of the screws and necessitated the same degree of exposure for removal of the plate when the fracture was healed. The Stader splint has also been used in a similar manner, but the thinness of the iliac wing in this area may lead to inadequate fixation.

The method used by the author is as follows:

With the patient under anaesthesia, the iliac crest is exposed through an incision paralleling the anterior border and the lateral surface of the iliac wing; the dissection is carried subperiosteally as far as the fracture line. Two stainless-steel pins, five thirty-seconds of an inch in diameter, are driven with a hand drill into the crest of the free fragment and between the two cortical surfaces, until the points of the pins can be seen at the fracture surface. The fracture is then reduced and the pins are driven into the cancellous portion of the adjacent surface. This gives immediate solid fixation of the fragment. The pins are cut off, with approximately one-quarter of an inch protruding out of the crest. The reflected muscles and the periosteal layer are replaced and sutured. After closure of the incision, the protruding ends of the pins can easily be palpated beneath the skin. After six weeks, the pins can be removed under local anaesthesia; a small incision is made in the skin over the subcutaneous ends of the pins and the pins are extracted with pliers.

The patient can be ambulatory almost immediately after pin fixation, as he is free from pain and there is sufficient stability of the fracture so that the reflected muscles have adequate anchorage, following suture, to allow full weight-bearing.

* Read at the fifteenth Annual Meeting of the Western Orthopedic Association, Yosemite, California, October 20, 1951.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Tracing made from roentgenogram in Case 1, showing a comminuted fracture of the right iliac wing.

Fig. 1-B: The tracing illustrates the pins in position, immobilizing the iliac fragment.

SEPARATION AT THE SYMPHYSIS PUBIS

Separation of the symphysis pubis is a not uncommon injury to the pelvis; it may result from anteroposterior or lateral compression or from direct trauma to the pubes.

FIG. 2-A

FIG. 2-B

Fig. 2-A: Comminuted fracture of right iliac wing in Case 2.

Fig. 2-B: After reduction of the fracture, pins were used to immobilize the loose fragment.

FIG. 3-A

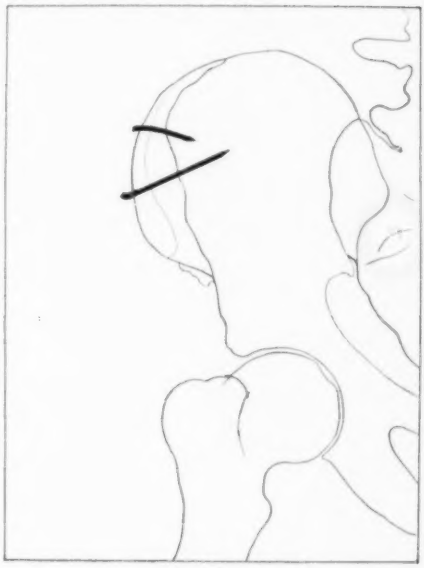

FIG. 3-B

Fig. 3-A: Drawing from roentgenogram in Case 3 illustrates fracture through the right iliac crest.
Fig. 3-B: Steinmann pins were used to immobilize the iliac-wing fragment after open reduction.

The majority of true separations of the symphysis pubis can be treated by immobilization of the pelvis in a pelvic sling. In some of the more difficult cases the method described by Watson-Jones is successful. The patient is placed in a lateral position, on the uninjured side, and a double hip spica is applied. At times, anaesthesia is required so that reduction can be carried out; after reduction the cast is completed.

The types of separation of the pubic symphysis which have been considered suitable for open reduction and internal fixation are those which fail to respond to conservative measures. Several patients with wide separation at the symphysis had overlapping of the pubis when compression was applied and separation recurred when the compression was released. No intermediate degree of compression could be maintained, either because of marked discomfort or because of the activity of the patient even during usual bed care.

Treatment

The most common technique of surgical treatment is wiring of the pubis; this may be very difficult, especially in the obese patient. Exposure of the symphysis pubis is not without danger and any procedure which minimizes the operative risk seems justified. Key and Conwell mention operative reduction in pelvic injuries, but feel it is rarely indicated. This viewpoint is held by the author of this paper. It is urged that operative reduction be reserved for the few cases of separation of the pubis, accompanied by marked subluxation of the sacro-iliac joint, in which reduction by manipulative means cannot be accomplished or maintained.

Under general anaesthesia, the pubes are exposed through a transverse incision along their superior margin. The operator can then accomplish reduction by grasping each side of the symphysis with heavy towel clamps and manipulating the pubes into position. By use of the carpenter's technique in joining two pieces of wood end to end, the pubes are toenailed together by a stainless-steel pin driven with a hand drill obliquely across the symphysis in both directions. As in open reduction of fractures of the ilium, the pins are cut off and a sufficient amount is left projecting so that the ends can be palpated beneath the skin after the incision has been closed. To prevent wandering of the pins deeper

FIG. 4-A

FIG. 4-B

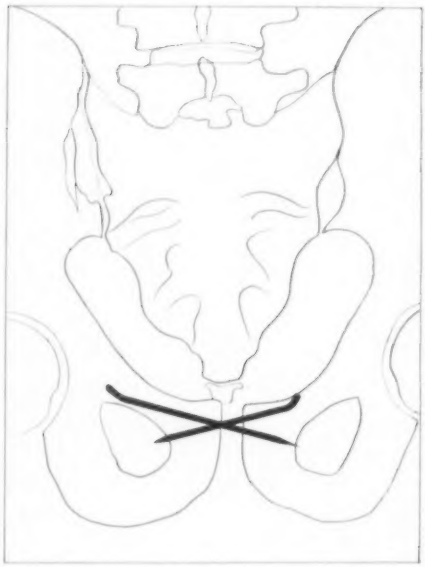

FIG. 4-C

Fig. 4-A: Tracing of roentgenogram in Case 4 shows wide separation of the symphysis pubis and dislocation of the right sacro-iliac joint.

Fig. 4-B: Pelvic-band suspension reduced dislocation of the sacro-iliac joint but produced marked overriding of the symphysis.

Fig. 4-C: Tracing of the postoperative roentgenogram illustrates maintenance of reduction by toenailing across the symphysis pubis.

into the soft tissues, it is wise to bend the protruding ends of the pins a few degrees. No immobilization has been found necessary following this operation and for physiological reasons this is to be expected, as the forces which tend to separate the symphysis exert a tightening effect upon the crossed pins.

Postoperative care is confined to making the patient comfortable in bed and prohibiting ambulation until sufficient fibrosis has occurred at the sacro-iliac joint or joints to insure stability. Here again, as in the case of pelvic fractures with sacro-iliac dislocation, an arthrodesis of the sacro-iliac joint may ultimately be necessary.

REPORT OF CASES

CASE 1. A white male, forty-eight years old, was pinned under a tractor on May 11, 1943. He sustained a fracture of the right ilium which, although not markedly displaced, could not be immobilized by external fixation (Fig. 1-A). The fragment moved with each respiration, producing constant pain. An open reduction with pin fixation (Fig. 1-B) was done on May 15, 1943, under local anaesthesia, the patient having been given morphine and scopolamine preoperatively. The patient was comfortable immediately after the operation and was up and about a few days later. The pins were removed under local anaesthesia on July 6, 1943. The patient was last seen on February 12, 1944, because of a shoulder injury. He was having no symptoms referable to the pelvis at that time.

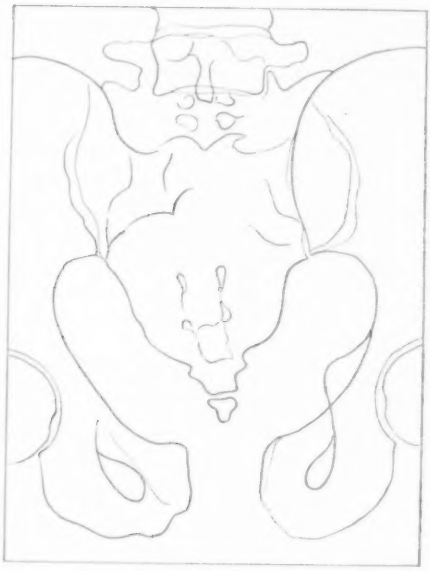

FIG. 5-A

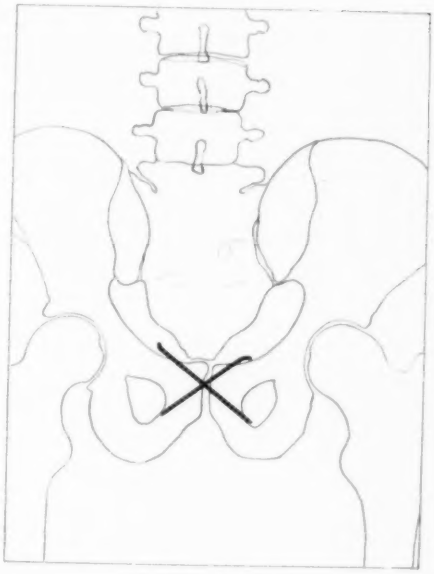

FIG. 5-B

Fig. 5-A: Wide separation of symphysis pubis in Case 5.

Fig. 5-B: Tracing of postoperative roentgenogram, showing reduction and nailing of symphysis pubis.

CASE 2. A white male, fifty-nine years old, was injured on July 15, 1944, when he was kicked by a horse. A fracture of the anterior third of the right ilium was found, similar to that in Case 1 (Fig. 2-A). The patient had had an amputation of the right lower extremity at the mid-thigh in 1943. External fixation proved ineffective in immobilizing the fragment or in giving relief of pain. Internal fixation of the fracture was done on July 20, 1944, and gave rigid immobilization of the fragment (Fig. 2-B). The patient was up on crutches three days later and was able to wear his artificial limb by September 1, 1944. The last examination, on September 10, 1947, disclosed no abnormal findings and the patient was symptom-free.

CASE 3. A white male, thirty-nine years old, was injured on August 3, 1944, in a bus accident while he was visiting in Wyoming. He was brought to the hospital by ambulance and examination disclosed a compound fracture of the right ilium (Fig. 3-A) and several fractured ribs.

The patient was treated by his attending physician until he was referred to the author for consultation on August 19, 1944. The patient was having constant pain from movement of the fragment with each respiration. There was no evidence of infection and the skin wound appeared to be healing satisfactorily.

An open reduction and pin fixation (Fig. 3-B) were done under local anaesthesia on August 21, 1944, and sulfonamide crystals were used in the operative wound because of its compound nature. The patient became ambulatory five days after surgery and was dismissed from the hospital on September 9, 1944. The pins were removed under local anaesthesia on October 8, 1944. The patient left for California on October 26, 1944, and has not been traced since that time.

CASE 4. A white male, fifty-five years old, was injured in a car accident on January 24, 1947. An examination disclosed that the patient had sustained a dislocation of the right sacro-iliac joint and wide separation of the symphysis pubis (Fig. 4-A), complicated by a sciatic-nerve paralysis. Following treatment for shock, the patient was supported in a pelvic sling and Buck's extension was applied to the right lower extremity. A chest complication developed and the patient became irrational on the following day. Two days later, a check-up roentgenogram disclosed overriding of the symphysis (Fig. 4-B). Correction was attempted by decreasing the weights, but roentgenograms disclosed a recurrence of the separation of the symphysis and sacro-iliac joint. On February 12, 1947, a manipulative reduction was attempted by the Watson-Jones method and a double hip spica was applied. Roentgenograms showed the symphysis pubis to be still widely separated.

An open reduction was carried out on February 19, 1947. After reduction of the symphysis, the position was maintained with two stainless-steel pins used to toenail the symphysis (Fig. 4-C). No external support was required and the patient had complete relief from pain. Hospitalization was prolonged because of the sciatic-nerve injury and the patient was not dismissed until May 2, 1947. The pins were removed on July 2, 1947. The patient returned to his usual duties as an insurance broker in August, 1947, but he died on February 18, 1949, from carcinoma of the stomach.

CASE 5. A white male, sixty years old, was injured on March 18, 1943, when a truck rolled over him while he was beneath it, working on the axle. He was brought to the hospital by ambulance. An examination disclosed a wide separation of the symphysis pubis (Fig. 5-A). Conservative treatment was unsuccessful and an open reduction with pin fixation was done (Fig. 5-B). The patient's period of hospitalization was prolonged, as he had sustained a fracture of the left ankle in the accident and was unable to begin weight-bearing until May 12, 1943. The patient died of a heart attack shortly after becoming ambulatory.

SUMMARY

In two types of pelvic injuries—fractures of the iliac wing and separation of the symphysis pubis—internal fixation with stainless-steel pins has given satisfactory results. This technique would appear to be easier and less time-consuming than the use of other types of fixation. No complications have arisen in the cases in which this has been used. The number of cases is small, as the necessity for operative reduction in pelvic injuries is rare.

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FLEXORPLASTY OF THE ELBOW

AN EVALUATION OF A METHOD

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Loss of flexor power in the elbow joint is a primary disability in the function of the upper extremity. To provide this articulation with active flexion is of the greatest interest to surgeons of reconstruction. In 1919, Steindler [1] described a method of restoring voluntary flexion to the elbow. In this procedure, the common origin of the superficial digital and wrist flexors is transplanted to a more proximal position on the humerus. This operation has since become known as a flexorplasty of the elbow. By 1944, Steindler [2] was able to report on the results in thirty-nine cases. Elsewhere, the number of adequately followed cases reported to date has been exceedingly small. Because the flexorplasty has been done relatively infrequently, it seemed of value to examine an adequate number of cases and to present the experience as a guide for the future. The purpose of the paper is to evaluate the total number of flexorplasties performed at the New York Orthopaedic Hospital.

MATERIAL

During the period June 1932 to June 1952, twenty-eight flexorplasties of the elbow were performed at the New York Orthopaedic Hospital by various staff members and

residents in training. One case could not be used in the final evaluation of this study. After the operation, the patient was discharged to the care of his family physician at a far-distant point. No data are available. All of the remaining twenty-seven patients received careful final evaluation. The authors personally examined nineteen of the twenty-seven patients. The rest were seen by colleagues on the Staff. One patient was reviewed seventeen years after the surgical procedure.

In eighteen patients, loss of elbow flexion was a result of poliomyelitis; in five cases obstetrical palsy was the etiological factor; and in five, trauma to the brachial plexus was the cause. Seventeen patients were males and eleven were females. The ages of the patients varied from eight to fifty-six years. Twenty-one per cent. were below ten and 75 per cent. were below twenty years.

OPERATIVE TECHNIQUE

The operative procedure, in general, was the same in each case. Through a curvilinear incision on the ulnar aspect of the elbow, the medial epicondyle was exposed. The ulnar nerve was identified and traced to its entrance into the flexor carpi ulnaris muscle. The median nerve was also identified and traced to its ramification into the flexor mass. The common origin of the superficial flexor mass was mobilized by removing with an osteotome a thin wafer of bone from the medial epicondyle. When more mobility was desired, the origin of the flexor carpi ulnaris was raised from the shaft of the ulna. The anteromedial surface of the humerus was exposed by subperiosteal dissection beneath the brachialis muscle. With the elbow in flexion, the common origin of the flexor mass was secured about an inch or more to a more proximal position on the shaft of the humerus. At times, a defect or a drill hole in the cortex was made. Other surgeons fastened the transplanted tendon entirely by suturing to soft tissue. A long plaster cast was applied from the hand to the axilla with the elbow in 45 to 60 degrees of flexion, and the forearm in neutral position between pronation and supination. In general, motion was started after the sixth week.

ANALYSIS OF DATA

Results

The longest period of evaluation in the study was seventeen years; the shortest was one year; and the average period was six years. This span gives a comprehensive scope of the activities of a group of patients with transplanted muscles over a sufficiently long period of time to encounter all deviations or changes.

At the time of the final evaluation examination, each result was rated as *good*, *fair*, or *poor*. A *good* result was that in which the flexorplasty was a distinct aid to rehabilitation by providing a useful range of motion with good to fair power (Fig. 1). The elbow joint in this group carried a fixed flexion deformity of about 40 degrees. A *fair* result was obtained when the patient was improved by the procedure, but the range of motion, the power of the transplanted muscle, or the position of the limb was not completely satisfactory. A *poor* result was one in which the patient was not improved by the flexorplasty. On this basis, the twenty-seven cases have been classified as follows:

Good	15	(56 per cent.)
Fair	7	(25 per cent.)
Poor	5	(19 per cent.)

In general, the age of the patient at the time of the operation seems to have made no difference in the result of the transplantation. Six of the patients were less than ten years of age; fifteen were between eleven and twenty years of age at the date of their operation; and four patients were between twenty-one and thirty. There was one patient each in the fourth, fifth, and sixth decades of life. The ratio of results remained constant.

The good and fair results can be considered together, since the patients were improved

by the operation. Prior to surgery, a contraction deformity of the elbow was a rarity. Following the operation, the patient could count on an average fixed flexion contracture of about 40 degrees. This is easy to understand when one appreciates the more proximal position of the placing of the origin of the flexor mass. The angle of 40 degrees is readily acceptable in a cosmetic evaluation and is a functional position of the elbow (Figs. 2 and 3).

Forearm Pronation

The flexor mass of muscles also function as pronators of the forearm, wrist, and hand. When the origin of the flexor-pronator group is tightened by transplanting it to a more proximal position on the humerus, a pronated position of the forearm occurs. Of course, a modifying factor in this is the power of the supinator group. When that is strong, there is less tendency to a fixed pronation defect. If it is weak, one must expect a greater tendency to a position of pronation in the forearm. A markedly pronated forearm has limitations when it is flexed to the face. However, the gain in the power of elbow flexion greatly offsets the pronation defect. When the supinators are quite weak, the pronation defect can be prevented by transplanting the flexor carpi ulnaris in such a way as to enable it to act as a supinator. This may be done either before or after the

FIG. 1

FIG. 2

Fig. 1: This patient had a good result. The right upper extremity had been affected by poliomyelitis. At rest there was no cosmetic defect such as gross flexion deformity of the elbow joint or marked pronation of the forearm.

Fig. 2: At rest there was a 40-degree fixed flexion deformity of the elbow. This is the average residual deformity which may be expected to occur in those with good results following a flexorplasty.

FIG. 3

FIG. 4

Fig. 3: Active flexion of the elbow brought the forearm to an angle of 25 degrees with the humerus. This gave an excellent range of motion of 115 degrees.

Fig. 4: Even though the superficial flexor mass of the forearm was used to flex the elbow, the patient had full use of the digits. In the photograph the patient is demonstrating the power to extend the digits and to oppose her reconstructed thumb at the same time as she flexes the elbow.

flexorplasty operation. In this series fixation of the transplanted mass to the anterior rather than to the medial surface of the humerus decreased the tendency toward pronation defect. Of the fifteen patients with a rating of *good*, ten had no pronation defect while three had such a defect. In two, this factor was not included in evaluation. In the *fair* category, seven of eight patients had a pronation defect. Thus, of those improved by flexorplasty, about one half showed a pronation defect.

Arthrodesis of Adjacent Joints

The value of arthrodesis of adjacent joints in relation to the result of the flexorplasty was considered. Shoulder fusion had been done in sixteen of the twenty-eight patients. It was found that the fusion contributed greatly to the total function of the upper extremity. In use, the elbow is elevated and the pull of gravity on the forearm is decreased. Flexion of the elbow becomes more powerful. However, the procedure did not specifically improve the function of the elbow. On the other hand, arthrodesis of the wrist has proved to be of great value in improving the power of flexion. Wrist fusion permits the active force of contraction to be concentrated at a few important joints rather than weakly dissipated throughout the distal portion of the extremity. The power of the weakened muscle is directed to the elbow and increases the power of flexion.

Good results were not correlated with the position of the arm after the flexorplasty and the length of time of immobilization seemed to be unrelated to end result. No relation was found between the result and the amount of supervised rehabilitation and exercise.

Analysis of Failures

The five poor results occurred in four patients. These have been reviewed carefully because we learn most from the reasons for failure. One patient had a flexorplasty at-

tempted twice on the same arm. In this patient, we found that the flexor mass had been inadequately mobilized and, therefore, could not be transplanted to an advantageous position. When the second attempt was made, scar tissue complicated the procedure. The record does not indicate a secure fixation of the transplanted muscle origin. A second patient did not have the muscle origin transplanted far enough proximally. The secure fixation of the transplant in the new site was questionable. The remaining two patients did not have enough power in the flexor-pronator mass prior to operation to produce elbow flexion even though a favorable position for the flexor muscle origin was obtained. One patient had an adequate range of motion with gravity eliminated. No flexion was possible with the elbow at the side. Another patient expending his total effort could only make one feeble move of the hand to the face.

It would seem, in these five operations, that an error in technique or an inaccurate preoperative evaluation of muscle power must have been responsible for failure. Technique can only be improved by familiarity with the proper method and an awareness of the anatomical requirements. Experience is the best instructor, not only in technique, but in the evaluation of muscle power. It is important to realize that the flexor power in the wrist and digits must come from the superficial flexor mass which is to be moved (Fig. 4). One cannot ask too much of a weakened muscle. Power in the deep flexors of the digits does not help in this reconstructive operation.

CONCLUSIONS

In reviewing the results in twenty-seven flexorplasties, the authors were impressed with the value of the operation. When at all possible, it is greatly to be preferred to other methods of restoring active flexion to the elbow.

A fixed flexion deformity of about 40 degrees should be expected. It is a functional position. There should be no hesitation from the viewpoint of appearance, for this angle does not constitute a cosmetic defect.

A tendency toward a pronated position of the forearm should be expected. If the supinators are strong, there will be balance. Insertion of the transplanted flexor mass into a more anterior position on the humerus was found to be an aid in diminishing this tendency. The use of the flexor carpi ulnaris as a supinator is also a method of preventing forearm pronation.

Great care must be given to evaluating the power of the flexor-pronator group of muscles prior to operation. The power located in the superficial flexor mass of the forearm is the most important. The power of these muscles is increased by arthrodesis of the wrist.

Knowledge of the technique of this operation should be exact. Adequate distal mobilization along the superficial flexor-muscle mass is most important. The adjacent nerves must be protected. The mass should be transplanted proximally and anteriorly on the humeral shaft. Secure fixation to the new site is mandatory. Utilization of cortical defects, such as drill holes, is helpful in achieving this fixation.

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THE FILUM TERMINALE SYNDROME

(The Cord-Traction Syndrome)*

BY GEORGE J. GARCEAU, M.D., INDIANAPOLIS, INDIANA

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This communication is a report of our observations made during the study and treatment of three patients presenting the symptoms of a progressive spastic paralysis. It concerns especially the pathological changes found when these patients were subjected to exploratory laminectomy. A diligent search of the available literature failed to reveal a similar clinical report, although such may exist.

In 1945 we became interested in the Arnold-Chiari syndrome. This symptom complex, usually associated with deformities of the spine and spinal cord, was first described by Arnold in 1894 and by Chiari in 1895. Many articles have appeared in the neurological literature since the publication of these original papers.

In a recent publication, McKenzie and Dewar concluded that in twenty-one of twenty-four patients operated upon for scoliosis with paraplegia, the cause of the paralysis was a tight dura stretching over the angulated spine. The review of the literature on the subject of paralysis associated with scoliosis supports that opinion. The onset of the paralysis in thirty-three of forty-one cases reported was between the ages of thirteen and nineteen years. Two of our patients were thirteen years old at the onset of paralysis. The third patient was fourteen years old at the onset of the symptoms; however, although he recovered and remained well for four years, the symptoms again recurred at the age of seventeen years.

Ingraham and Lowrey reported that about 25 per cent. of children have defects of the vertebral laminae and that incomplete closure is frequently observed.

Steele reported the Arnold-Chiari malformation to be a frequent factor in cases of hydrocephalus, causing a block of the fourth ventricle and obstruction of the cerebrospinal-fluid circulation.

Lichtenstein described the distant (remote) neuro-anatomical complications of spina bifida. He reported that the cauda equina may be short, causing retention of the infantile position of the conus medullaris.

Harmeier in 1933 and Tarlov in 1938 described the normal structure of the filum terminale and concluded that it contained all the histological tissues of the spinal cord.

Reimann and Anson and later Anson alone studied an instance of a sacral cord in an anatomical laboratory specimen, the only sacral cord in 129 specimens. The spinal cord terminated at the first and second lumbar vertebral level in 95 per cent. of 129 adult specimens.

Kleinberg recently reported a case of paraplegia occurring in a patient with a congenital scoliosis. He concluded that, if the symptoms do not improve with non-operative treatment, laminectomy supplemented by the necessary additional surgery is indicated.

In the patients who form the basis of this report, progressive spastic palsy developed while they were under observation for other conditions. The first had a congenital scoliosis; the second had recovered from tuberculosis of the spine; the third had been under treatment for an idiopathic scoliosis.

Case 1. In August 1944 a thirteen-year-old white boy was admitted to the Orthopaedic Service for observation and treatment for a rapidly progressing left thoracic kyphoscoliosis, due to extensive congenital malformations of the spine from the second to the seventh thoracic vertebrae (Fig. 1-A). He had

* Read at the Joint Meeting of the Orthopaedic Associations, London, July 2, 1952.

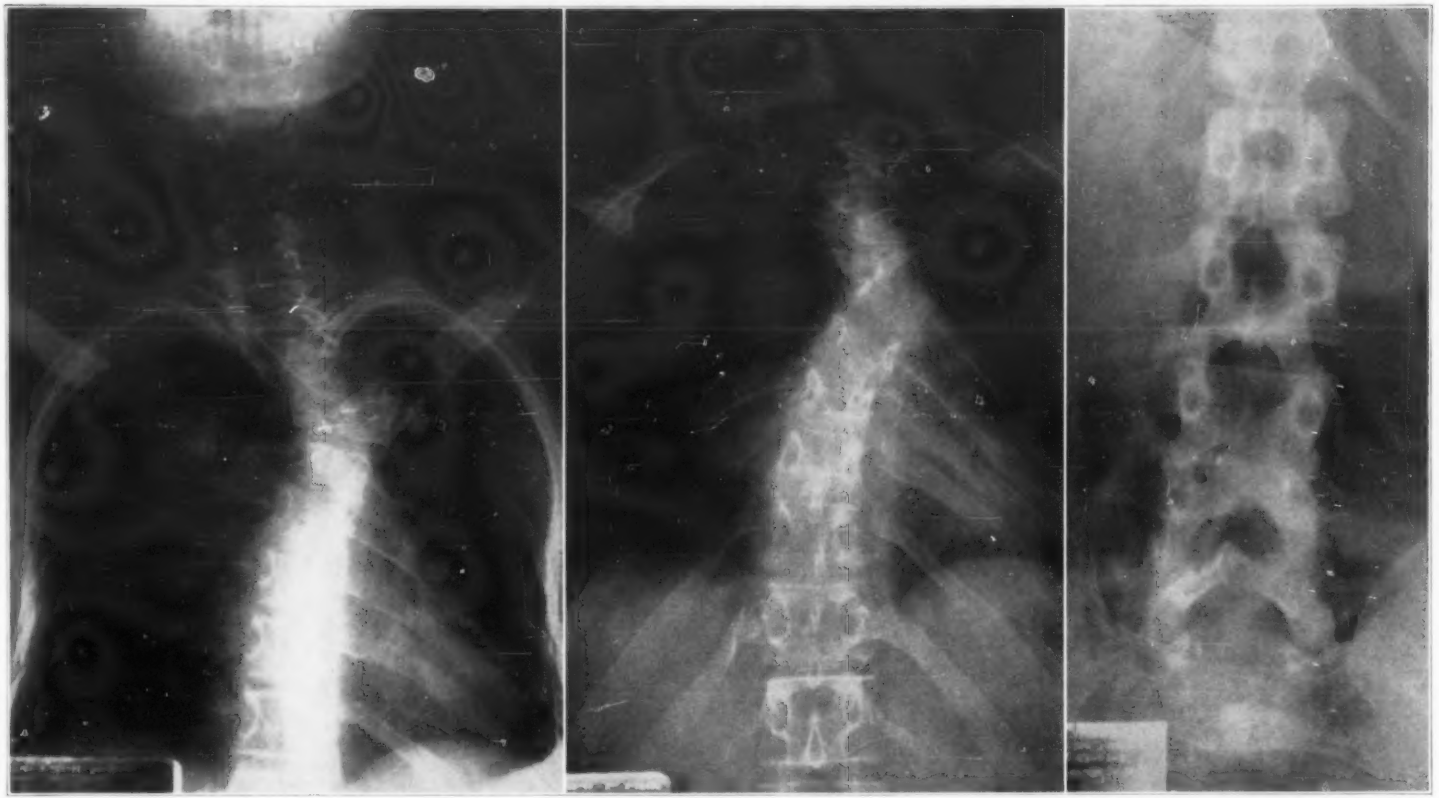

FIG. 1-A
August 1944

FIG. 1-B
November 1946

FIG. 1-C
November 1946

Minimal increase in left thoracic scoliosis due to congenital anomalies of thoracic vertebrae and of the second, third, and fourth lumbar vertebrae. Lumbar and sacral laminectomy revealed a tight filum terminale and conus medullaris at the level of the second sacral vertebra. There was slow but good recovery.

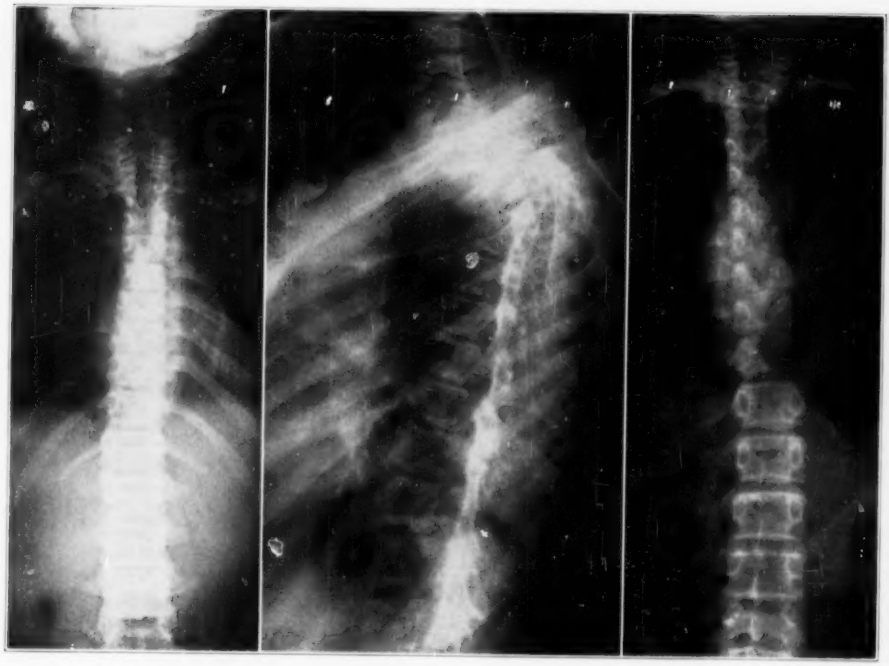

FIG. 2-A
November 1945

FIG. 2-B
September 1949

FIG. 2-C
September 1949

Case 2, H. S. Tuberculous spondylitis from the second to the fifth thoracic vertebrae inclusive. Sound fusion had occurred spontaneously. The filum was sectioned and there was partial recovery.

recently complained of pain in the back on exertion. There was a severe razor deformity of the back. The neurological examination was negative. Eleven months later he was again admitted for further study because of stiffness and clumsiness in the legs. There was spasticity of the legs, equinus of the ankles, bilateral Babinski reflexes, depressed knee jerks, and dull cremasteric reflexes; the abdominal reflexes were absent. The spinal-fluid total protein was 122 milligrams per 100 cubic centimeters and the globulin was ++. Improvement occurred after treatment on a frame with head-and-neck traction. A spine fusion was performed on December 17, 1945. Three months later he had completely recovered.

The patient was not observed again until October 1949, at the age of seventeen years, when he reported for a recurrence of the paralytic symptoms. There was paralysis of the bladder and of the bowel. The examination suggested a lesion at the tenth thoracic segment of the spinal cord. The spinal fluid was about the same as on the initial admission. Three laminectomies were performed by the neurosurgeon, the cord being uncovered from the third cervical to the sixth thoracic vertebra. No constrictions were encountered. The spine fusion was found to be sound. A fourth laminectomy from the second lumbar to the second sacral vertebrae was performed on February 2, 1950. The spinal cord was found to extend to the level of the second sacral segment and was anchored by a large filum terminale. The filum terminale was sectioned. Slow but progressive improvement followed. Bladder and bowel function returned. He now walks well without support.

CASE 2. A thirteen-year-old colored boy was admitted to our Service on February 21, 1951, with the complaint of tingling, weakness, and stiffness in the right leg. He had a quiescent tuberculosis of the spine from the second to the fifth thoracic vertebra, inclusive, which had responded to three years of conservative treatment on a frame (Figs. 2-A, 2-B, and 2-C). He had become ambulatory at the age of five years. The physical examination revealed a tall, thin colored boy with a severe kyphosis in the upper thoracic spine. He stood with a wide base. There was weakness in both legs, more in the right than in the left. All the reflexes in the lower extremities were hyperactive. There were Babinski and Rossolimo reflexes bilaterally. Vibratory sense was diminished and positional sense was altered. Pain and touch sensation appeared intact. All symptoms became aggravated while he was under conservative treatment and bed rest. Because a filum terminale was suspected, a laminectomy was performed on March 7, 1951. A thick, tough, and tight filum

terminale was found. Stimulation of the filum gave no response; the filum was therefore resected. Microscopic examination of the specimen revealed a fibrous-tissue band with a few scattered nerve fibers. Because of fear of overlooking pathological changes at the thoracic kyphos, a laminectomy was performed at that level on March 20, 1951. Sound fusion had occurred spontaneously. There was severe angulation of the cord (90 degrees). No actual compression was observed, although pulsation was not definite below the gibbus. The postoperative course was marked by a transient total paralysis of the right lower extremity and increased weakness in the left. There was also hypo-aesthesia of the lower extremities. Slow improvement has occurred.

Case 3. A fifteen-year-old white girl had been admitted to the James Whitcomb Riley Hospital in April 1947, for observation and treatment of a right idiopathic thoracolumbar scoliosis (Fig. 3-A). At that time good correction was obtained in a turnbuckle jacket. Spine fusion from the third thoracic to the second lumbar vertebrae, inclusive, was performed on July 18, 1949. She was followed in the Out-Patient Department. Lengths of the lower extremities remained equal. One-fourth inch of atrophy developed in the right calf. The neurological examination remained negative. In July 1950, she complained of nausea, vomiting, dizziness, and dragging of the left leg. The only positive neurological observations were a loss of tendon reflexes in the left upper extremity, and a possible Babinski reflex on the left side. Four months later a Babinski and an unsustained ankle clonus were found on the left side. In February 1951, a slight weakness of the left grip was noted. Spinal-fluid examination was normal. Severe headaches developed, as well as a tendency to fall, and weakness and pain in the right hand. Examination revealed the fundi to be normal and no signs of cranial involvement were found. There was weakness in the right hand and in the left lower extremity. The left leg was hyperalgesic. Position sense was intact. Co-ordination was normal. Deep reflexes were absent in the arms. Abdominal reflexes were absent. There was a reversed radial reflex (that is, when the distal end of the radius was tapped, the elbow did not flex and the fingers had a tendency to extend) as well as a Hoffmann sign on the right. The left knee jerk was hyperactive. The ankle jerks were equal. There was unsustained patellar and ankle clonus on the left side. Babinski, Chaddock, and Rossolimo reflexes were present on the left side. Our impression at that time was that a high cervical cord compression, due to cord traction, existed. A spinal-puncture attempt was discontinued for fear of injury to a sacral cord if such existed.

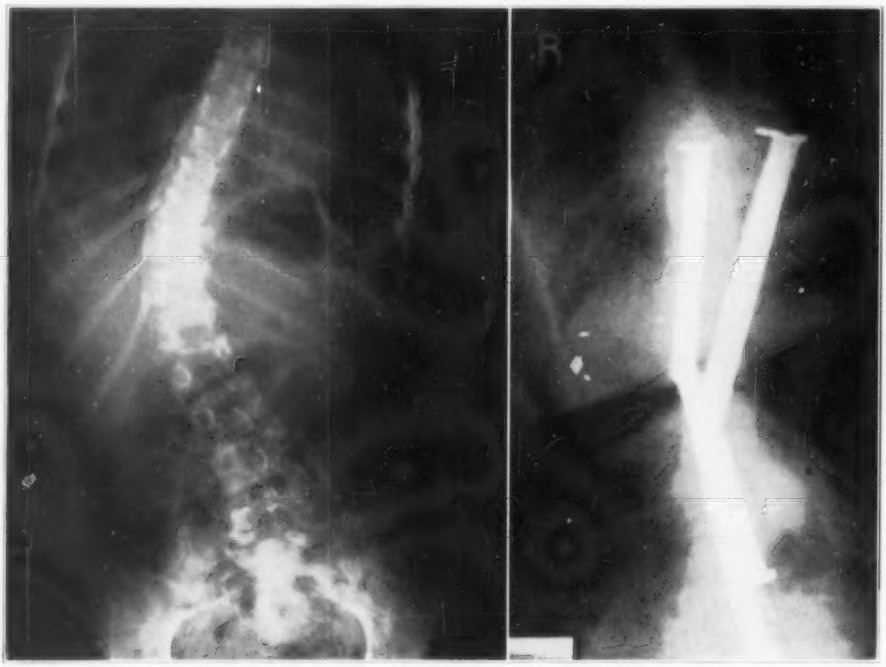

Fig. 3-A

April 1949

Case 3. A. H. Idiopathic right thoracolumbar scoliosis of 50 degrees.

On May 16, 1951, a laminectomy of the fifth lumbar and first sacral vertebrae was performed. A mild spina bifida was found. The ligamentum flavum appeared to constrict the dural sac. Two small dural bands stretching across the dura at the fifth lumbar level were severed. The arachnoid was normal. The filum was five millimeters in diameter and very tense. When the filum was severed, the ends separated one centimeter. The postoperative course was uneventful and almost complete recovery has occurred (Fig. 3-C).

The paresis in this patient was not caused by a tightness of the dura over the angulated spine. There were neurological symptoms in the upper extremities which could not have been caused by a thoracolumbar scoliosis.

FIG. 3-B

July 1950

Correction maintained. Onset of symptoms of nausea, vomiting, and ataxia. Filum terminale was sectioned in May 1951, followed by good recovery.

DISCUSSION

The cord-traction symptoms associated with dysraphism have been recognized by neurosurgeons for many years. The neurosurgical literature abounds with excellent articles. The syndrome has been associated with simple spina bifida occulta, meningocele, myelomeningocele, diastematomyelia, congenital scoliosis, Klippel-Feil syndrome, cranium bifidum, tight fibrous bands, and bony spicules. All of these conditions may be associated with congenital deformities, especially in the lower extremities. These are usually evident at birth. The neurological abnormalities may be progressive.

The associated pathological lesions were different in the three cases here reported. In the first patient the tight filum terminale had prevented the distal migration of the spinal column, so that the conus medullaris had retained the foetal position. Paralysis occurred during the period of rapid growth.

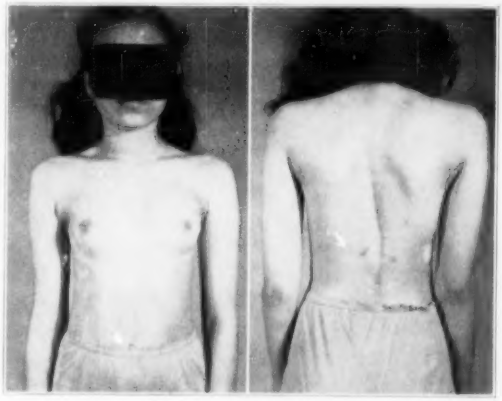

FIG. 3-C

January 15, 1952

Shows satisfactory maintenance of correction of scoliosis.

In the patient with tuberculosis of the spine the signs and symptoms of paraplegia developed during the period of rapid growth. Recovery followed sectioning of the filum terminale. Exploration at the area of kyphosis failed to reveal the cause of the paralysis.

In the patient with idiopathic thoracolumbar scoliosis, the filum separated one centi-

meter on sectioning, indicating the tightness of the structure. The symptoms in the upper extremities could not have been caused by stretching of the filum over the angulated spine. Almost complete recovery followed sectioning of the filum.

Unfortunately we do not know the level of the conus medullaris in two of the cases. In the patient with the idiopathic scoliosis we could assume that it was below the usual level of the first or second lumbar vertebra, because it separated one centimeter when cut.

Our treatment of the patients could be questioned. Decompression of the foramen magnum could have given the same result. We are following these patients and may later find that foramenotomy will be necessary.

The tight filum terminale may cause spinal-cord compression over an angulated spine. It may also cause cord traction, pulling the hind brain into the foramen magnum.

The question of the role of the tight filum terminale as a cause of idiopathic scoliosis is suggested but remains unanswered. We are now attempting to produce scoliosis in monkeys by preventing the migration of the spinal column away from the conus medullaris.

CONCLUSIONS

A tight filum terminale may cause the cord-traction symptoms known as the Arnold-Chiari syndrome. The orthopaedic surgeon frequently is the first to observe the patient presenting the symptoms, and, therefore, may direct the patient properly.

NOTE: The author wishes to express his appreciation to Dr. Robert F. Heimburger, Associate Professor of Surgery (Neurosurgery), Indiana University School of Medicine, for his valuable help.

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CAVERNOUS HEMANGIOMA OF STRIATED MUSCLE

A Review of the Literature and a Report of Four Cases

BY KENNETH G. JONES, M.D., LITTLE ROCK, ARKANSAS

Hemangiomata are not rare tumors; they are found in almost all the vascular structures of the body. Cutaneous nevus vinosus, or port-wine stains which blanch on compression, and their antithesis, the capillary form, which responds poorly to pressure, are the most common members of this large pathological family. Nevertheless, hemangiomata of the special organs have been shown by routine postmortem examination to occur more often than has been suspected, but, because of their deep-seated location, they are not so frequently seen by the physician. Even though they attain considerable size, these tumors have, in many instances, remained asymptomatic and undetected by their hosts.

Liston in 1843 described an erectile tumor of the popliteal space, recording the first case history of hemangioma of muscle. Sixty-five years later, in 1908, Davis was able to compile 147 case histories of the lesion, to which he added six of his own cases. In 1930, with Kitlowski, he again studied the literature to enlarge this total to 256 cases. Shallow, Eger, and Wagner in 1944 thoroughly reviewed the subject to amass 335 cases, while by 1950 Bonvallet was able to collect twenty-two additional cases and described one which he had observed in the "*court supinateur*" for a total of 358 cases. He tabulated these lesions as occurring in the frequency shown in Table I.

TABLE I

Distribution of 358 Hemangiomata of Muscle (after Bonvallet)

Location	No. of Patients	Location	No. of Patients
Head	27	Upper arm	43
Neck	12	Hand	10
Thorax	40	Buttocks	9
Diaphragm	1	Thigh	74
Abdomen	14	Leg	64
Back	13	Foot	8
Shoulder	10	Not stated	1
Arm	32	Total	358

The present author will describe four cases in patients whom he has had occasion to treat.

DESCRIPTION OF CASES

Case 1. (B.M.) A seven-year-old white girl was admitted to The Arkansas Children's Home and Hospital on July 18, 1950. She complained of pain within an area of swelling located in the upper half of the anteromedial aspect of the left forearm. Pain had been present for two weeks prior to admission. The swelling had not been observed until after the onset of pain. The child's parents asserted that she no longer used the involved upper extremity as freely as the contralateral one. Observation by the house and nursing staffs supported this contention.

The patient's systemic history failed to disclose significant past or familial illnesses. There was no history of associated trauma or of a recent febrile reaction.

Physical examination revealed a normal, well developed girl who did not appear to be acutely ill. Located within the anteromedial portion of the left forearm in the proximal half (Fig. 1-A) there was a firm, non-compressible, non-pulsating swelling, measuring approximately three by five centimeters. The skin over the enlarged segment was slightly warmer than the surrounding area and tender to touch, but freely movable. A thrill was not palpable, a bruit was not audible, nor was light transmissible. Sensation and arterial pulsation in the extremity were normal. Motion in the joints above and below the mass, as well as pronation and

supination, was complete although slightly painful at extremes. Muscle tone and power were good but moderately diminished on the involved side. The arm lengths were equal.

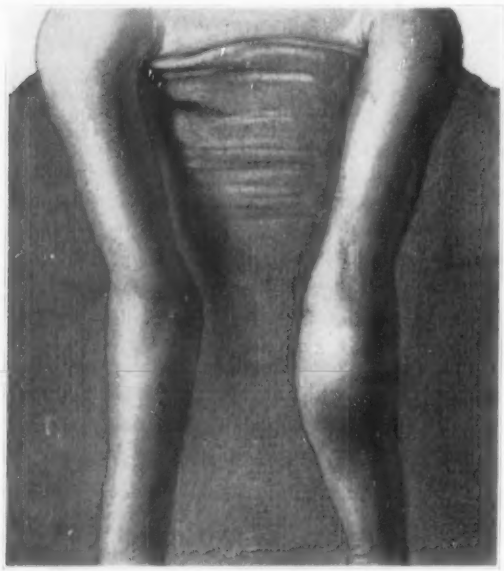

FIG. 1-A
July 18, 1950.

Routine laboratory examinations, as well as determinations of serum calcium, phosphorus, and alkaline phosphatase, were within normal limits.

Roentgenograms of the patient's skull and chest failed to display abnormal densities or rarefactions. Anteroposterior and lateral roentgenograms of the left forearm (Fig. 1-B) revealed a reaction in both the periosteum and the endosteum involving the proximal half of the shaft of the ulna, resulting in thickening of its cortex. There was a suggestion of an onion-peel laʼmination with subperiosteal and intramedullary new-bone formation, but no tendency toward "sun-ray" striation. In spite of its increased diameter, the cortex did not appear to be sclerotic. A small osteochondroma was noted on the medial surface of the humerus about the junction of its middle and lower thirds.

A tentative diagnosis of Ewing's sarcoma or atypical osteomyelitis was made, and on July 21, 1950, a biopsy of the ulna was performed through an incision over its superficial border. On direct examination, the periosteum was seen to be thickened and the cortex broadened by newly deposited periosteal and endosteal bone. The bone marrow appeared to

FIG. 1-B
July 18, 1950.

FIG. 1-C
September 18, 1950.

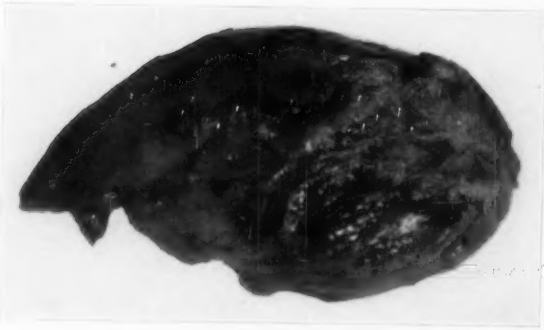

FIG. 1-D

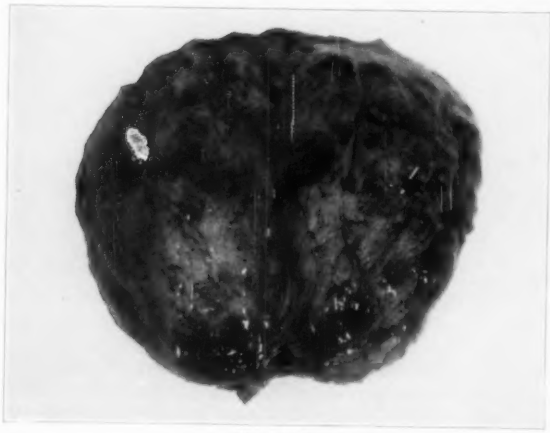

FIG. 1-E

FIG. 1-F

be normal. Exploration of the soft tissues in the immediate vicinity of the bone disclosed only normal muscle. The wound healed by primary intention, but the pain of which the patient had complained before biopsy was unaltered by this procedure.

Microscopic examination of the specimen evidenced sclerosis of the cortex, a mild degree of fibrosis of the marrow, and an increase in eosinophils. Bacterial examination of the tissue removed was negative for tuberculosis, fungi, and routine organisms. The true nature of the disease process remained unknown when the patient was discharged on August 10, 1950.

On September 18, 1950, she was readmitted because of increasing pain and swelling within the anteromedial aspect of the left forearm. The findings on examination were the same, except for obvious enlargement of the mass. Laboratory findings were again within normal limits, but roentgenographic examination (Fig. 1-C) clearly delineated a circumscribed swelling within the soft tissues of the volar surface of the left forearm. The bone defect created in the ulna by the previous biopsy was observed to be healing. The ulnar shaft appeared as previously described.

On September 21, 1950, under a tourniquet, through a volar, muscle-separating incision over the apex of the swelling, the mass was explored. The flexor digitorum sublimis was found to be displaced radially by a firm, bluish, mottled tumor mass the origin of which was from that portion of the flexor digitorum profundus muscle which supplies the index and middle fingers. It was removed *in toto*. A large vein leaving the proximal end of the tumor was isolated and ligated. The distal tendons of the index and middle fingers were sutured to the profundus tendons of the ring and little fingers.

The resected tumor (Fig. 1-D) was comma-shaped and measured three by three by five centimeters. Its external surface was composed of a dirty-grey fibrous capsule which was covered superficially by stretched muscle fibers and through which at irregular intervals bluish sinusoids could be seen. When the mass had been sectioned (Fig. 1-E), a dense fibrous matrix with numerous large, thin-walled, vascular channels was

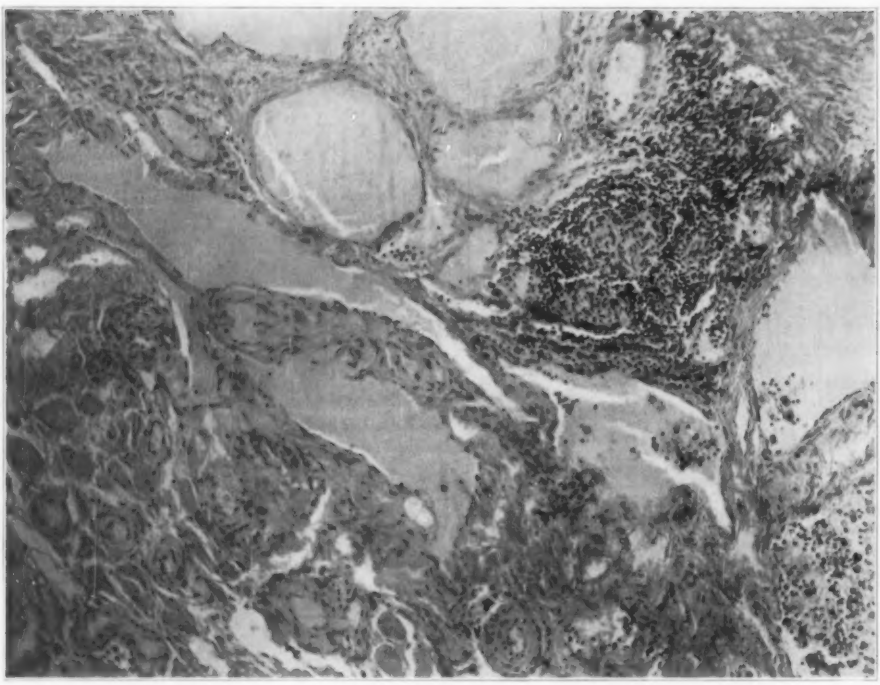

FIG. 1-G

conspicuous. Microscopic examination (Fig. 1-G) demonstrated numerous endothelium-lined spaces which ranged from capillary to cavernous in size. Most of these sinusoidal spaces contained red blood cells. The stroma consisted of a loose to dense fibrous tissue. Blood vessels with thickened fibrotic walls and muscle fibers, most of which had undergone early degenerative changes with loss of nuclear structure, were evident throughout the lesion, as well as numerous collections of perivascular lymphocytes. There was no evidence of malignancy. The diagnosis was cavernous hemangioma of the left flexor digitorum profundus.

The wound healed by primary intention. Within a few weeks, normal function of the extremity had been restored, and there has been no recurrence of pain or swelling.

The patient was last seen one and one-half years after surgery, at which time no evidence of recurrence was found (Fig. 1-F). In February 1953 her name was still on the roll of the Crippled Children's Division, and it can be assumed that, if there had been any recurrence or other difficulty, we would have been informed of it.

CASE 2. (R. L.) A white male, aged twenty-seven, entered St. Vincent's Infirmary complaining of pain and swelling behind the right knee which had been intermittently evident since the age of eight and had become constant during the past three years. The mass had gradually increased in size. It was not reducible and had never been red but was tender on occasions. There was no known history of trauma. There were no other masses; however, during childhood, the patient had suffered a chronic osteomyelitis involving other extremities.

Examination revealed a firm, warm, non-reddened, non-fluctuant, non-reducible, slightly tender mass in the lateral half of the right popliteal space opposite the knee joint. The mass was not within the skin or subcutaneous tissue and did not transilluminate. Motion of the knee joint was complete. Muscle tone and power of the calf were normal. Neurological changes in the extremity were not present.

Routine laboratory examinations were normal.

Rentgenograms revealed an increased soft-tissue density which arose beneath the deep fascia posterior to the lateral aspect of the right knee joint.

A preoperative diagnosis of Baker's cyst was made, and on July 12, 1951, the lesion was explored under a tourniquet through an S-shaped incision placed posteriorly. On incision of the deep fascia, the mass was found to have its origin within the substance of the lateral head of the gastrocnemius muscle. The tumor consisted of large bluish cavernous sinuses within a firm stroma both of which were displacing the muscle. The lesion was fairly well circumscribed, so that it could be removed without sacrificing the most lateral

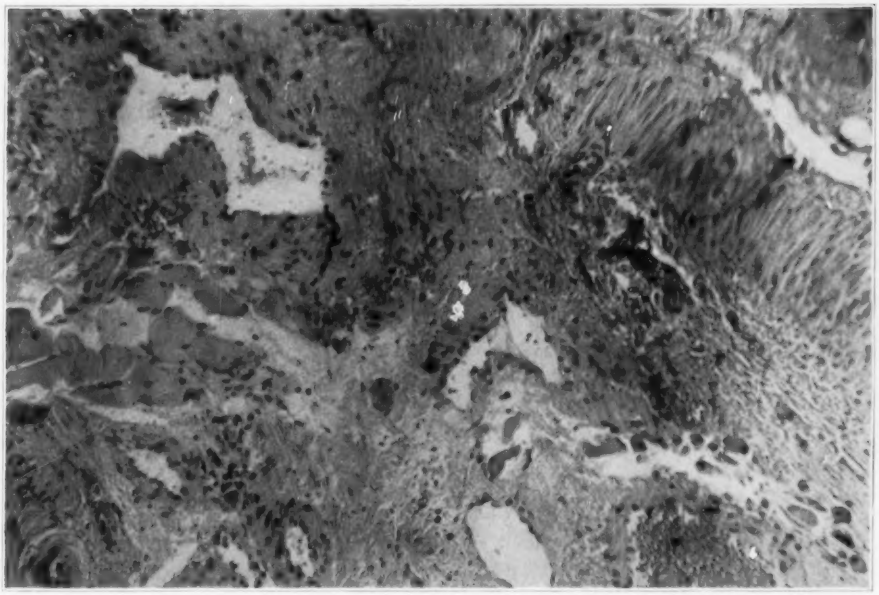

FIG. 2

portion of the lateral head of the gastrocnemius muscle and its investing fascia. Thereby, functional integrity of the calf muscle group was maintained.

The resected tumor measured three by five by six centimeters. Grossly and on cut section, in size and consistency as well as appearance, the specimen resembled that in Case 1. Microscopic examination (Fig. 2) revealed the single-layered endothelium-lined spaces and focal collections of lymphocytes to be more numerous than in the former specimen. The thick-walled blood vessels prominent in Case 1 were not so numerous. Degenerating muscle bundles were prominent. The diagnosis was cavernous hemangioma of the lateral head of the right gastrocnemius muscle.

The wound healed by primary intention. Normal, symptomless function of the extremity has been restored without evidence of recurrence.

The patient was re-examined on March 21, 1953. Function in the involved extremity had remained normal and there was no evidence of recurrence.

CASE 3. (D. M. J.) This patient was a colored girl, eight years of age, who complained of a swelling over the anteromedial aspect of the right thigh of four years' duration. The patient associated the onset of swelling with a fall which resulted in an injury to the right thigh. Pain had never been evident in the mass. In response to questioning about enlargement, the patient stated, "It grows as I grow". Neither increased heat nor redness had been observed. Other than the usual childhood diseases, the past history was negative.

Examination (Fig. 3-A) revealed a firm, non-tender, non-fluctuant, non-compressible, slightly warm mass, measuring approximately three by four inches, arising deep to the deep fascia over the anteromedial aspect of the right thigh just proximal to the patella. The skin was pliable over the mass. Function of the knee joint was normal. The mass was made more firm by contraction of the quadriceps. It failed to transilluminate. A thrill was not palpable nor was a bruit audible. A tourniquet above the mass failed to alter its size.

Findings at routine laboratory examinations were within normal limits.

Roentgenograms showed an elliptical soft-tissue swelling within the muscle mass of the anteromedial aspect of the lower third of the right thigh just above the knee joint. There were three small calcifications (phleboliths) within the mass. Alterations in the structure of the femur were not evident.

A diagnosis of cavernous hemangioma of the right quadriceps muscle was made, and on December 20, 1951, under a tourniquet through an anteromedial incision, the tumor was exposed (Fig. 3-B). A large cavernous plexus was found to be poorly isolated within the substance of the lower half of the right quadriceps muscle, involving all four of its components and extending down into the conjoined suprapatellar tendon. By cutting across normal muscle proximally and laterally and across the conjoined tendon distally, we were able to remove the lesion completely. The suprapatellar defect created thereby was repaired by

bridging the gap with a fascial graft, together with medial transposition of the remaining fibers of the vastus lateralis and transplantation of the sartorius muscle into the patella.

The removed specimen measured two by eight by eight centimeters. Grossly, the lesion differed from that in the previous two cases in that fibrous tissue, while evident, was less marked and the tumor less well circumscribed. Microscopically (Fig. 3-C) the picture differed from Case 1 in that thick-walled vessels were not observed, degenerating muscle bundles were more numerous, and the fibrous stroma was more loose and less evident. In some areas, thin-walled sinusoids composed of single layers of endothelial cells were seen to rest directly upon muscle. The diagnosis was cavernous hemangioma of the right quadriceps muscle.

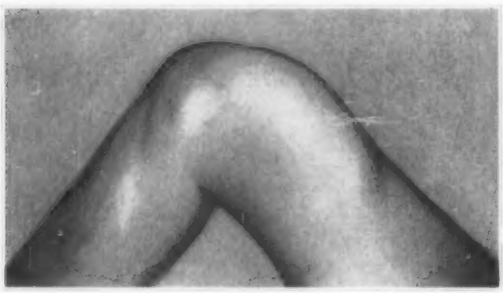

FIG. 3-A

The patient was re-examined on March 28, 1953. She had not experienced pain in the thigh since shortly after removal of the lesion. There was no physical evidence of tumefaction. The range of active and passive motion of the right knee was between 90 and 180 degrees, with strong positive extension of the knee primarily by the transplanted sartorius muscle.

CASE 4. On June 8, 1953, D. L., a fourteen-year-old white female, was admitted to

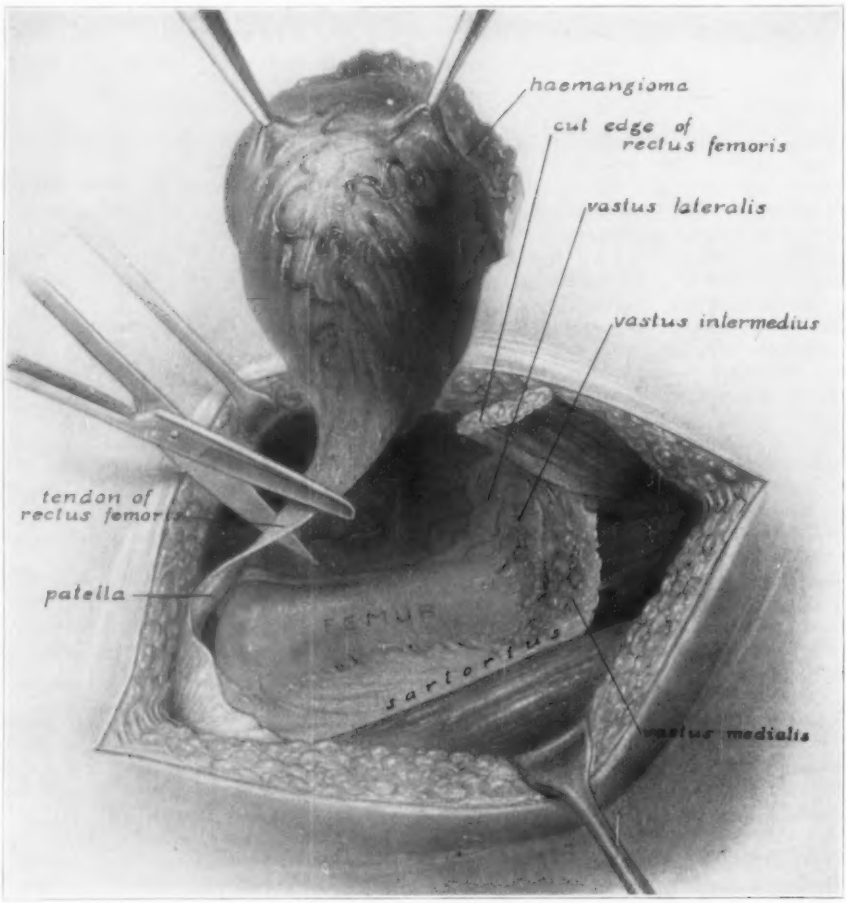

FIG. 3-B

FIG. 3-C

St. Vincent's Infirmary with the complaint of a painful swelling over the dorsal aspect of the right foot between the third and fourth metatarsals. The swelling measured two by three centimeters and was located deep to the subcutaneous tissue. It was intermittently painful, slightly compressible, tender, non-fluctuant, and did not transilluminate light. An overgrowth of approximately three millimeters was noted in the third toe.

Roentgenograms of the right foot demonstrated a soft-tissue swelling between the third and fourth metatarsals with spreading of the bones. Sclerosis and notching of the cortex of the third metatarsal were evident. Phleboliths were not noted. A diagnosis of cavernous hemangioma of the interosseus between the third and fourth metatarsal of the right foot was made.

On the following day, under a general anaesthetic and with a tourniquet, the lesion was removed. There was minimal extension of veins from the muscle into the subcutaneous tissues of the dorsal aspect of the foot. However, the lesion was obviously arising from the interosseus between the third and fourth metatarsals. Microscopic examination of the removed specimen demonstrated a typical cavernous hemangioma of muscle. The lesion involved the greater portion of the interosseus between the third and fourth metatarsals.

The period of postoperative observation is short, but the patient's condition is satisfactory and no recurrence is anticipated.

In addition to those presented, the author has been able to find fifteen cases (Table II) of cavernous hemangiomata of muscle not included in Bonvallet's review of the subject.

INCIDENCE

Kornmann has asserted that hemangiomata constitute 7 per cent. of all benign tumors occurring in man. Weaver, upon analysis of 142 cases of hemangiomata of the deeper structures of the lower extremities, found that 107, or 76 per cent., occurred within the muscles, and in those cases in which the growth had its origin within muscle, it was confined to one muscle in 66 per cent.

In a review of 1,308 hemangiomata observed at Memorial Hospital in New York, Watson and McCarthy noted the neoplasm to have been located within muscle in ten instances. Jenkins and Delaney on studying 256 cases of muscle angiomata found that in those instances in which the age of onset was given, 47 per cent. occurred during the first decade of life, while 79 per cent. were evident by the end of the second decade, and that 94 per cent. were demonstrated before the patient was thirty years of age. In 70 per

TABLE II

REVIEW OF KNOWN CASES NOT INCLUDED BY BONVALLET

Authors	Description of Cases and Location	No. of Cases
Elkin and Cooper, 1947	Sixteen cases of diffuse hemangioma. Site of origin could not be determined in all cases. The following sites of origin were established: masseter and temporal muscles (2); intrinsic muscles of hand (1); frontalis (1); vastus lateralis (1); muscles of shoulder (1); and latissimus dorsi (1).	7
Gotfryd, 1947	Cavernous hemangioma arising from the paravertebral muscles and producing sciatica. Removal was successful.	1
Barr and Reidy, 1948	Cavernous hemangioma of medial head of gastrocnemius in a boy fifteen years of age.	1
Forconi and Ficai, 1948	Cavernous hemangioma arising within the muscles of the forearm.	1
Camera, 1949	Cavernous hemangioma of peroneal muscles in a male ten years of age. Partial resection was followed by a recurrence so that total resection was necessary.	1
Corsi, 1949	Primary hemangioma of the extensor digitorum longus communis.	1
Chipps and Weiler, 1950	Erectile cavernous hemangioma of the masseter muscle in a white man nineteen years of age. Excision without recurrence.	1
Immink, 1950	Cavernous hemangioma of the thigh containing approximately 0.5 liter of blood.	1
Bertoglio, 1951	Cavernous hemangioma of the flexor muscles of the right forearm.	1
Jones, 1953	Cavernous hemangiomata of the flexor digitorum profundus, lateral head of gastrocnemius, quadriceps, and interosseus between third and fourth metatarsals.	4
Previously reported cases (Bonvallet, 1950)		358
Total of known reported cases to date		377

cent. of their reported cases, the lesions were located within the muscles of the extremities.

ETIOLOGY

There is no unanimity of opinion concerning the etiology and pathogenesis of hemangioma. It is most likely, however, that hemangiomata are congenital in origin.

CLASSIFICATION

Classification of hemangiomata, like that of neoplasms in general, is not universally agreed upon. From Boyd's simple division into capillary and cavernous types, attempts at classification extend to Watson and McCarthy's monumental clinicopathological grouping with eight divisions. Nevertheless, almost all hemangiomata of muscle which have been reported are described as cavernous and consisting of endothelium-lined sinusoids supported by a fibrous matrix, the proportion of sinusoids to fibrous stroma being subject to considerable variation. Most of these lesions are benign. Geschickter and Keasbeay have stated that less than 1 per cent. of benign angiomata become malignant.

CLINICAL FINDINGS

In hemangioma of muscle, the presence of a swelling, with or without pain, is the most common complaint. Examination revealed a mass in 98 per cent. of those cases reviewed by Shallow, Eger, and Wagner. Pain was a complaint in only 60 per cent.

Pain, when present, may be constant, intermittent, or recurrent. It may be experienced only on contraction of the muscle or when external pressure is applied. On occasions, the mass is so sensitive that palpation must be carried out under anaesthesia. The patient's pain may be localized, referred, or radiating along a nerve trunk; it may be sharp or dull, mild or severe. A sensation of pressure within the mass is sometimes complained of by the

patient. Pain is most often evident when the lesion is found in one of the narrow muscles, such as the sartorius.

A demonstrable swelling may be soft or hard, tender or non-tender, with approximately equal incidence. The consistency of the lesion is primarily dependent upon the proportion of vascular spaces to fibrous stroma. Swellings as small as a pea and as large as a foetal head have been described. The outline of the mass may be sharp or poorly defined, while the surface may be smooth or nodular. Pulsations and bruits have been observed rarely, while the deformity usually cannot be completely reduced under pressure. As a rule, the skin and subcutaneous tissue are not involved and can be demonstrated as freely movable over the muscle and deep fascia, but bluish discolorations due to dilated veins and ulceration of the skin have been observed. Seldom does elevation of the extremity or application of a tourniquet alter the size of the swelling. Transillumination is not possible. Careful examination will in most instances locate the mass within or attached to muscle.

Limitation of motion and impairment of function may result from an expanding growth. Motor and sensory impairment resulting from damage to peripheral nerves may be encountered. Hyperaemic hypertrophy and anaemic atrophy of the involved extremity have been reported.

A roentgenogram is a most helpful diagnostic aid. If two-plane views are taken for both bone and soft-tissue detail, the true nature of the lesion in many instances will be suggested, and in some instances it can be established. Bone changes are observed infrequently. Shallow, Eger, and Wagner mentioned a periosteal reaction in six of their cases, while this reaction constituted one of the most outstanding findings in the author's first case. Depending upon its site and location, a soft-tissue mass may be delineated by an oval shadow adjacent to or attached to, but not arising from, the neighboring bone. Phleboliths, usually multiple, found in approximately 50 per cent. of all cases, are, when present, visualized as densely calcified, sharply outlined, oval areas within the tumor shadow. These opacities must be differentiated from calcified parasites such as are found in trichiniasis, which are much smaller, and Cysticerci, which are usually elongated and less dense. On occasions, calcification of a large area is demonstrable.

Pomeranz and Tunick state that "The most accurate aid to diagnosis which we possess is the injection of a radiopaque substance in order to visualize and identify the lesion."

DIFFERENTIAL DIAGNOSIS

Shallow, Eger, and Wagner stated that a correct diagnosis has been made preoperatively in only 19 per cent. of all reported cases. Undoubtedly this poor showing is, more than anything else, due to failure of the clinician to consider hemangioma of muscle as a possibility. But, in addition, because of its deep-seated location and its extremely variable size, shape, and consistency, the true nature of the lesion is often difficult to establish. Barr and Reidy, in discussing one case, emphasized this difficulty.

The most usual error in differential diagnosis is to regard the growth as a lipoma. Both tumors are slow-growing, but confusion of one for the other should not occur if it is remembered that fatty tumors of muscle are extremely rare and if examination of the lesion is adequate to determine that the mass is deep to the subcutaneous tissue. A diagnosis of primary carcinoma of muscle has been considered, but this condition does not seem to occur in muscle. Hygroma and dermoid cyst are seldom found outside their classical locations. Myoblastomata and rhabdomyomata occur with extreme infrequency. Acute abscesses, osteomyelitis, and phlebitis are prone to be associated with toxic symptoms and a systemic reaction. Patients with a simple hemangioma of muscle as a rule appear healthy. Neurofibromata and fibromata grow rapidly and have well defined borders. Chronic myositis is suggested by a deep, painless, brawny thickening attached to bone, while myositis ossificans is usually seen roentgenographically hiding behind its dotted veil.

Hematomata can often be diagnosed by aspiration. Syphiloma and varicose veins, in contrast to hemangioma of muscle, are classically seen in the later decades of life and should not be confused with it. Arteriovenous aneurysms are infrequently congenital and, as a rule, a thrill and a bruit are demonstrable and may be associated with other cardiovascular changes. Tuberculosis of muscle is not seen frequently and, if present, is likely to be associated with evidence of that disease elsewhere. Muscle herniae are usually seen to distend through a well circumscribed opening on contraction and to become reduced spontaneously upon relaxation. The x-ray should, in most instances, rule out tumors arising from bone. Hydatid cysts, which are very rare, like ganglia yield a serous fluid on aspiration. The absence of a history of penetration should eliminate the possibility of a foreign-body reaction.

Biopsy or partial resection as a means of diagnosis would seem to be indicated only when exploration revealed that the lesion is not resectable.

PATHOLOGY

Hemangiomata seldom metastasize but are often sufficiently destructive to be regarded as locally malignant. The origin of the tumor seems most likely to be from misplaced embryonic mesenchyme deposited in the perimysium. Its growth by infiltration is like that of a malignant neoplasm, endothelial buds being sent out between neighboring muscle bundles which degenerate beneath their onslaught. Muscle is replaced by a fibrous connective tissue which supports capillaries, thin-walled sinusoids, hypertrophied arterioles, and collections of lymphocytes.

Gross examination *in situ* usually reveals the host muscle to be distended by engorged cavernous sinuses which protrude between the uppermost muscle bundles. On palpation, the turgescence may be firm, soft, or rubbery in consistency, depending upon the proportion of fibrous matrix to sinusoids. It may be possible to delineate a well circumscribed outline, or transition into normal muscle may be so gradual that the limits of invasion can be determined only on transection of the muscle. The growth may infiltrate the tendon.

On section, the cut surface is usually greyish white, with yellow fatty areas and isolated muscle groups in various stages of degeneration. Vascular spaces of various size are seen in an inconstant proportion. In some cases, the cut ends of the vessels stand out like pipes. Nerves may be found within the tumor stroma. Phleboliths and areas of ossification are often located if sought for.

Microscopically, the outstanding feature is the large number of vascular spaces lined by a single layer of endothelium. The lacunae vary from capillary to cavernous in size and communicate freely. Groups of degenerating muscle fibers, focal collections of inflammatory cells, and large fibrotic arteries may be demonstrable. Normal veins can be found, especially near the periphery of the accretion. Thrombosis, sclerosis, and hyalinization of vessels is usually observed. Phleboliths, organized thrombi impregnated with tricalcium phosphate, may be encountered.

Connective-tissue septa constitute the matrix of the growth. Fibroblastic proliferation may be so marked as to resemble a fibrosarcoma.

The degree of inflammatory reaction is often in direct proportion to the patient's complaint of pain.

TREATMENT

The forms of treatment recommended for hemangioma of muscle are many and varied. Ointments, pastes, and poultices have been applied to the skin, while magnesium darts and ivory pegs have been inserted beneath it and sclerosing agents injected into it with little success. Cole and Hunt, while not specifically discussing hemangioma of muscle, were enthusiastic in their recommendation of the use of boiling water as advocated by

Wyeth for thermal coagulation of the blood and scalding of the intima. Except for Reder, few other authors have used it so successfully; perhaps because of the special technique required.

Carbon dioxide snow and electrocoagulation are not indicated.

Radiation by both x-ray and radium has failed to prove a satisfactory means of controlling hemangioma of muscle. In many instances, no effect has been observed, and since these growths are prone to occur near joints in children, the possibility of epiphyseal distortion renders it potentially dangerous in many cases.

Iontophoresis with sodium salicylate has been accredited by Pegri as curing a giant hemolymphangioma in a three-year-old child, but it seems more reasonable to assume that the patient's cure resulted from a spontaneous thrombosis and regression of the growth.

At present, complete surgical excision under a tourniquet is unquestionably the treatment of choice. Partial resection has, in many instances, been reported as permitting a recurrence. A bloodless field is imperative for successful removal of the lesion.

Amputation in the case of solitary hemangioma of muscle should not be resorted to either through erroneous diagnosis of a malignant tumor or through fear of a fatal hemorrhage during resection, but should be reserved for those diffuse, spreading hemolymphangiomata which have failed to be controlled by any other means.

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A Historical Review of the Studies and Investigations Made in Relation to Human Gait

(*Continued from page 542*)

giving this symphonic score of concerted muscle activity depth as well as width, so as to make it tridimensional, figuratively speaking.

These refined and convenient electromyographic methods of later days are indeed a long cry from Braune and Fischer's laborious attempts to calculate muscle efforts over the devious route of mathematical computations.

We see at long last with great satisfaction that kinetics of the human body, the most difficult part of which is kinetics of gait, has come into its own. So long as the investigations were confined to the normal, the rank and file of orthopaedic clinicians showed only passing interest. Since it has become apparent that the kinetic analysis of gait has developed into a guide for clinical practice and an effective adviser in difficult and controversial situations, a definite change has come about.

It is only necessary now, it seems to us, to unfold to the student these problems of kinetic analysis of normal and of pathological locomotion in more simple and more plausible form. The older classics on human gait, especially Braune and Fischer's, conceded nothing to the reader's possible shortcomings in physical and mathematical groundwork, and most of these publications are painfully difficult reading. So much more must be appreciated the more simplified and more intelligible methods in which Dr. Inman and Dr. Saunders presented at the London Meeting what they have called the major determinants of gait. Dr. Slocum's graphic stroboscopic demonstration of the prosthesis gait is of the same high order. These investigators have shown that an interest and an understanding of the problems can best be served by refining the manner of presentation, couching them in more acceptable and more simple terms, and by applying greater didactic skill in unfolding difficult kinetic situations.

It is to be expected that this will be a major issue in the future when the kinetics of the human body becomes fully accepted in clinical practice; when it is given equal rank with anatomy and pathology; and when it is finally realized that without this ancillary science no orthopaedic training can be called adequate.

Arthur Steindler

A STUDY OF ONE HUNDRED AND FOUR CONSECUTIVE CASES OF FRACTURE OF THE HIP

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In 1934, a series of 100 consecutive fractures of the neck of the femur was reported in the *Journal of the American Medical Association*[1]; the report included studies of the method of treatment, mortality, and end results. This article presents an analogous study of 104 consecutive fractures of the neck of the femur treated since the publication of the first paper. The majority of the fractures in this series were treated by internal fixation, by means of either Smith-Petersen cannulated nails or Smith-Petersen nails with Thornton plates. The operative technique varied somewhat according to the individual surgeon, but all patients were operated upon by the authors in the same Hospital.

With the development of the Smith-Petersen nail for the internal fixation of the fractured femoral neck, a definite advance was made in the treatment of the fracture.

TABLE I

DISPOSITION AND TREATMENT *

	No. of Cases	Deaths in the Hospital	Died in less than Six Months	No. for Evaluation	Bony Union	Non-Union	Aseptic ** Necrosis
No treatment	6	5	1	0	0	0	0
Traction only	14	4	0	10	4	6	1
Nailed through small lateral incision	46	3	6	37	33	4	7
Nailing open shaft ***	33	1	0	32	30	2	8
Open reduction	5	1	0	4	3	1	0
Totals	104	14	7	83	70	13	16

* Of 104 patients admitted to the Hospital with a fractured femoral neck, five patients died before any definitive treatment could be rendered; one was sent to a mental hospital. In addition, nine patients died while under treatment, before union of the fracture could be expected; seven more patients died in less than six months. Eighty-three patients thus remained for evaluation.

** Patients with aseptic necrosis are in addition to those with non-union.

*** Exposure was made through an adequate lateral incision.

Early ambulation became possible; this lowered the incidence of pneumonia and reduced the time spent in the Hospital. It was hoped, by accurate reduction and fixation, that the incidence of non-union, extensive absorption, and late aseptic necrosis of the head of the femur would be reduced. Early reports in the literature suggested this possibility, but the re-establishment of the local blood supply still seems to be dependent on factors beyond the control of the surgeon.

It is possible to nail all fractures, regardless of the age or physical condition of the patient. This was made possible to a large degree by the advance in the administration of regional and general anaesthesia.

The earlier fractures in this study were reduced and were nailed in the operating room, the nail being introduced through a lateral thigh incision after the introduction of Kirschner wires. Its position was checked by serial x-rays in both anteroposterior and lateral planes. The later fractures were operated upon under fluoroscopic control, with a resulting reduction in operating time. A large number of the later fractures were operated

TABLE II

FRACTURES OF THE FEMORAL NECK 1937 TO 1949
AT MASSACHUSETTS MEMORIAL HOSPITALS

Total number of patients			104
Private patients		70	
House patients		34	
Age range	30 to 90 years (age mean: 68)		
Deaths in the Hospital		14	
Patients receiving definite treatment		98	
Patients for whom no treatment could be offered		6	
Patients unsuitable for operation		14	

upon by means of a technique in which only a small incision was made about the Kirschner wire selected under fluoroscopic control as the most centrally located to allow for the introduction of the Smith-Petersen nail.

After satisfactory nailing, bed rest was continued for a period of two weeks, unless symptoms appeared of impending pulmonary complications, mental deterioration, or other geriatric problems in old people confined to bed. Under these circumstances, the patient was more actively mobilized to a chair and crutches.

Weight-bearing was allowed at varying periods postoperatively, at the preference of the operating surgeon, ranging from one week to twelve weeks, with the greatest number of patients being permitted weight-bearing between three and six weeks. It was unfortunate that the actual time of weight-bearing was not recorded in a large number of the early cases. All patients were given careful instructions in walking and sitting so that the affected limb was not externally rotated at any time.

As shown in Table I, fourteen patients died while in the Hospital under treatment, and seven more died in the first six months after operation. This left a total of eighty-three patients for evaluation. Bony union was obtained in seventy patients, or 84 per cent. Of these, aseptic necrosis of the head developed to some degree in ten, but there was union at the site of the fracture. Non-union occurred in thirteen patients. Thirty-seven fractures were nailed through a small lateral incision; thirty-three by exposure of the lateral shaft of the femur; and five by exposure of the head and neck. There seemed to be little difference in the end result whichever the method used.

As seen in Table III, of the eighty-three patients available for evaluation, all were followed for at least nine months, and seventy-five patients were followed for a year or more. Six patients were alive and were seen at follow-up examination ten years after the initial treatment.

Table IV is a comparison of the present series with the series reported in 1935. It will be seen that, although the immediate mortality rate in the Hospital was lower in the present series, there was little change in the mortality rate in the six-month period after injury. In the present series, the causes of death were:

Cardiac failure	5
Pneumonia	2
Pulmonary embolism	4
Nephritis	1
Cerebrovascular accident	1
Thyrotoxicosis	1

Table V is an analysis of the causes for non-union. All fractures with non-union showed incomplete reduction with one exception. In two patients, a second reduction and nailing was attempted and a satisfactory position was obtained, but in both fractures non-union developed. In one patient whose fracture had been adequately reduced and whose femoral

TABLE III

FOLLOW-UP OF PATIENTS
(Series of 1937 through 1949)

Patients Known to be Living and Seen at Follow-up	Length of Follow-up (*Years*)
83	9 (months)
75	1
64	3
30	4
17	5
11	7
8	8
6	10

TABLE IV

A COMPARISON OF THE TWO SERIES

1934 Series			
Total number of patients			100
Untreated (died)		1	
Treated		99	
Whitman spica		71	
Died	15		
Union	31		
Non-union	12		
Unknown	13		
Traction		28	
Died	3		
Union	13		
Non-union	4		
Unknown	8		
Age extremes			12 to 89 years (mean age: 67)
Mortality in the Hospital			19 per cent.
1950 Series			
Total number of patients			104
Untreated (died)		6	
In the Hospital		5	
In less than 6 months		1	
Treated		98	
Smith-Petersen nail		84	
Died in the Hospital	5		
Died in less than 6 months	6		
Union	66		
Aseptic necrosis	15		
Non-union	7		
Traction		14	
Died in the Hospital	4		
Union	4		
Aseptic necrosis	1		
Non-union	6		
Age extremes			30 to 90 years (mean age: 68)
Mortality in the Hospital			13.4 per cent.
Total deaths in less than 6 months			21

TABLE V

ANALYSIS OF NON-UNIONS *

Method of Treatment	No. of Cases	Incomplete Reduction	Position		Nailed Twice	Rotation of Head	Nail too Short, with Distraction
			Varus	Valgus			
Traction only	6	6	6	0	0	6	0
Nailing through small lateral incision	4	3	3	1	2	1	1
Open shaft nailing	2	1	2	0	0	1	0
Open reduction	1	0	1	0	0	0	0
Totals	13	10	12	1	2	8	1

* Exclusive of patients who died in the Hospital or in less than six months, as well as other patients who were unsatisfactory for inclusion, as shown in Table I.

head had been placed in a valgus position, non-union developed. As might have been expected, traction alone proved to be inadequate fixation, and non-union was the common result; in six of the ten patients so treated who were available for evaluation non-union developed. It may be that insufficient pull was applied, as all fractures treated by traction were incompletely reduced, with some varus deformity persisting. A careful study of all hips suggested that union was more likely to occur with the fracture reduced completely in anatomical position.

When the reasons for aseptic necrosis were analyzed, incomplete reduction, again, was the common finding, with varus deformity, apposition of 80 per cent. or less, and unreduced rotation present either in combination or as a single factor (Tables VI and VII). However, even with adequate reduction and fixation, too early weight-bearing may be a factor and should be avoided.

TABLE VI

ANALYSIS OF FIFTEEN CASES OF ASEPTIC NECROSIS EXCLUSIVE OF THOSE WITH NON-UNION

Method of Treatment	No. of Cases	Position *		Weight-Bearing **		Apposition of Less than 80 per cent.	Rotation	Bony Union		Result ***	
		Varus	Valgus	Early	Late			3 Mos.	6 Mos.	Good	Bad
Nailed: Through small lateral incision	7 †	3	3	4	3	3	2	5	2	4	3
Nailed: Open shaft	8 ††	3	5	3	5	5	3	5	3	3	5
Totals	15	6	8	7	8	8	5	10	5	7	8

* One patient is omitted. He was treated by traction only.

** Early weight-bearing is defined as weight-bearing permitted in less than one month. Late weight-bearing, in most cases, means limited weight-bearing with crutches for three months. In four patients, the only predisposing factor to aseptic necrosis seemed to be early weight-bearing,—that is, these patients all had had excellent reduction and had given early evidence of bony union in less than one month after nailing. Three patients had good results three to five years later; one patient had a poor result due to flattening of the femoral head and arthritis.

*** Bad results in eight patients are attributable to arthritis and resorption of variable amounts of the femoral head and neck with shortening.

† One fracture was nailed twice.

†† One patient from another clinic with non-union and aseptic necrosis of fourteen months' duration was successfully treated with bone-grafting.

TABLE VII

Nail Centrally Located and Reduction 90 to 100 per cent.		Nail Eccentrically Placed, Reduction Less than 80 per cent., or Both	
Union	55	Union	11
Non-union	2	Non-union	5
Died	10	Died	1
Total	67	Total	17
Aseptic necrosis	7	Aseptic necrosis	8

Further study of the x-rays of all patients with non-union revealed that obliquity of the fracture line (Table VIII), with incomplete reduction, was present in all patients with non-union. Obliquity of the fracture line makes reduction difficult to obtain and to maintain at the time of operation and may be a justifiable reason for open operation. Poor location of the nail was the important factor in only three patients, two patients with non-union and one with aseptic necrosis. In all three, it was necessary to remove the

TABLE VIII

CLASSIFICATION ACCORDING TO LOCATION AND TYPE OF FRACTURE

Type of Fracture	No. of Cases	Union	Non-Union	Died
Femoral neck				
Transverse	26	18	5	3
Oblique	33	22	6	5
Subcapital				
Unclassified	3	3	0	0
Transverse	13	11	1	1
Oblique	3	2	0	1
Unclassified	26	14	1	11
Totals	104	70	13	21

nail and, after a second reduction, to re-insert it in a more central location in the head and neck. In all three, the nail was in the anterior and superior part of the head and neck after the first reduction and nailing, and it broke through anteriorly. In one of these patients in whom the nail was in a poor position non-union occurred in spite of the valgus position of head.

In nine patients the fractures were re-nailed—in three because of poor location of the nail, and in six because of incomplete reduction or loss of reduction after nailing. In two

TABLE IX

No. of Cases	Union	Non-Union	Aseptic Necrosis	Died in Less than Six Months	Died in the Hospital
		Head in Valgus Position after Reduction and Nailing			
30	22	4	7 *	1	1
		Head in Varus Position after Reduction and Nailing			
28	12	9	8 **	3	3
		Head in Anatomical Position after Reduction			
25	25	0	0	0	0

* In five patients who had aseptic necrosis, the end result was satisfactory.
** In two patients who had aseptic necrosis, the end result was satisfactory.

TABLE X

TIME WEIGHT-BEARING PERMITTED *

Time Weight-Bearing Permitted (*Weeks*)	No. of Cases	Union	Non-Union
1	1	1	0
2	9	8	1
3	8	6	2
4	9	9	0
6	17	15	2
8	11	9	2
10	2	2	0
12	6	6	0
16	4	0	4
Totals	67	56	11

* Time in which weight-bearing was permitted was not recorded for thirty-seven patients. Twenty-one patients died in six months after operation, fourteen of whom died in the Hospital.

patients, the nail backed out, and fixation was lost. Of these, one patient was subjected to re-nailing three times—a Thornton plate was added at the third re-nailing. In this patient union occurred. Of those whose fractures were re-nailed, union occurred in three, non-union developed in five, and one died within six months of the re-nailing. In all patients the re-operation was done during the first Hospital admission. The nail was removed in eight patients; in seven of these the nail was removed after union had occurred because of the discomfort caused by the protrusion of the nail through the lateral cortex. In the remaining patient, the nail was removed because of non-union and extensive absorption of the femoral neck.

Thirty-two patients were lost to follow-up after one year. Of this group, there was non-union and evidence of aseptic necrosis in three when they were last seen.

A review of the roentgenograms of patients with union who were lost to follow-up after one year revealed the probability that union would be maintained. No comment can be made at such an early date as to the possibility of aseptic necrosis.

An autogenous bone peg from the tibia was used in five patients. The bone peg was introduced through a drill hole carried through the neck into the head from the lateral cortex after the exposure of the head and neck and visual reduction. The fracture was still further fixed with Moore pins, a Smith-Petersen nail, or both. One patient died in the Hospital; non-union developed in one patient with absorption of much of the neck and head; union occurred in three. In one of the three patients in whom union occurred the hip became ankylosed through calcification of the joint capsule.

A study of all patients in whom reduction and nailing had been done (the head being nailed in valgus position) revealed that of thirty patients, union occurred in twenty-two—five of these had a minor amount of aseptic necrosis; four of the thirty patients had non-union; and two had extensive aseptic necrosis with an unsatisfactory result (Table IX). Of the twenty-eight patients in whom reduction was incomplete and in whom a varying amount of varus deformity still persisted, union occurred in only twelve, and two of these had a minor amount of aseptic necrosis; non-union developed in nine of the twenty-eight, and six patients had extensive aseptic necrosis with a poor end result. It is interesting to note that all cases of non-union and aseptic necrosis occurred in the group of patients in whom either a varus or a valgus deformity was present after reduction. Union occurred in all hips in which anatomical position had been obtained at reduction (Table IX). In hips with a varus position of the head after reduction and nailing, there was a tendency

to aseptic necrosis, non-union, or both. Only one patient with non-union, who was living after six months, was suitable for an additional operative procedure. This patient was treated early in the series, and a stable hip was obtained by means of a McMurray osteotomy. Other patients suffered too much mental deterioration or general debility to be suitable for further surgery.

SUMMARY

One hundred and four consecutive fractures of the neck of the femur were reviewed. Fourteen patients died in the Hospital, and seven more died within six months of injury, leaving eighty-three patients for evaluation. All patients were followed at least nine months, sixty-four patients have been followed for three years or more, and six patients for ten years. In thirteen patients non-union occurred and in sixteen patients aseptic necrosis of a varying degree developed. Analysis of all cases of non-union and aseptic necrosis suggested that incomplete reduction with persistent varus deformity was the commonest cause of poor results. Overcorrection with the head in a valgus position did not necessarily ensure union as had been suggested by some observers [2,3,4]. Our study suggests that obliquity of the fracture line may require open reduction for accurate reduction and fixation. Union occurred in seventy of the eighty-three patients available for evaluation.

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PARAPLEGIA RESULTING FROM TUBERCULOSIS OF THE SPINE *

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STATISTICAL STUDY

This study includes 122 patients at Sea View Hospital who had paraplegia due to tuberculosis of the spine during the fourteen years from 1937 to 1950 inclusive. During this period of fourteen years there were 510 patients with tuberculosis of the spine under our care at that institution. Since in 122 of these paraplegia developed, the incidence was 23.9 per cent. There were forty-seven white and seventy-five colored patients. Eighty-three patients were male and thirty-nine female. The average age was 30.1 years, the oldest patient being sixty-nine years and the youngest two years. Color and sex had no specific influence on success of treatment (Table I).

* Read at the Section on Orthopaedic Surgery of the American Medical Association, Chicago, Illinois, June 10, 1952.

TABLE I

INCIDENCE OF PARAPLEGIA IN TUBERCULOSIS OF THE SPINE

		No. of Patients
Patients with tuberculosis of the spine		510
Patients with paraplegia		122
White	47	
Colored	75	
Male	83	
Female	39	

TABLE II

AGE DISTRIBUTION

Range of ages		2 to 70 Years
Average age		30.1 Years
Age Groups (*Years*)	Spines Involved (*Per cent. of Series*)	Paraplegia (*Per cent. of Series*)
0 through 9	16.83	12.29
10 through 19	15.05	22.95
20 through 29	25.25	17.21
30 through 39	19.64	19.67
40 through 49	14.79	12.29
50 through 59	6.63	11.48
60 through 70	1.78	4.09

There were ten paraplegics between the ages of two and five years; there were an additional five between the ages of five and ten years. Therefore, in fifteen instances paraplegia occurred below the age of ten (Table II). These children showed the greatest percentage of favorable outcome. Comparing the age incidence of paraplegia with the general age incidence of tuberculosis of the spine, one finds that paraplegia occurred in approximately the same ratio except for the first decade. During that period the incidence of paraplegia was definitely lower than the incidence of tuberculous involvement of the spine.

Condition on Admission

There were forty-seven paraplegics who on arrival were in such desperate condition that nothing could be done for them; all forty-seven eventually died. Of these, twenty-six had hopelessly advanced pulmonary disease. Overwhelming multiple osseous lesions, bilateral renal disease, multiple sinuses in the spinal area, infected old surgical wounds, and massive decubiti, as well as inanition, psychotic state, refusal of surgery even by desperately ill patients, and the condition following laminectomy, all had influence on the fatal outcome. Combinations of these adverse findings were frequently encountered. These forty-seven patients were never operated upon by us. At admission conference all were noted to be patients in the hopeless terminal phases of tuberculosis, for whom nothing but custodial care could be provided.

This leaves a balance of seventy-five patients for whom there was thought to be a possibility of salvage. Many of these patients were also in desperate condition on arrival. None of them could be considered as having a favorable prognosis, in view of the known tuberculous spine lesion together with paraplegia or paresis. Of these seventy-five patients whom we thought there might be some possibility of saving, the majority were sent in, with the expectation of a fatal outcome, by other hospitals after months or years of treatment. Sea View is the end resting place for any tuberculous patient in the New York City hospital system for whom it is thought that nothing else can be done.

Status of the Paralysis

Ninety-nine of the 122 patients had complete paraplegia, motor and sensory; twenty-three had paresis or partial paralysis. All of these had sustained clonus and varying amounts of motor weakness and sensory loss. A patient with incipient paraplegia which is not permitted to go on to total loss of function has a much better prognosis than a patient with complete paraplegia. Only one of the twenty-three patients with paresis succumbed, while sixty-eight of the ninety-nine patients with complete paraplegia died. To prevent a paresis from developing into a full-blown paraplegia demands early recognition and prompt surgery. With such care, the prognosis for permanent recovery is excellent. With late diagnosis of extradural pressure in tuberculosis of the spine and so-called conservative treatment, the outlook is poor. Early recognition demands, as part of the routine examination of any patient with tuberculous spinal disease or suspicion thereof, the inclusion of observation of clonus, Babinski, and other reflex changes. The outstanding early objective sign is clonus.

Diagnosis

Diagnosis of this condition rests upon the known fact of tuberculous involvement of the spine together with sustained clonus. All of the other findings of gradually increased pressure, such as Babinski, weakness, and sensory change eventuating in complete paraplegia, may be present in addition. Since tuberculous epidural abscesses extend beyond recognizable limits, spine taps must be avoided. Meningitis may result from dural puncture.

All of the 122 cases of paraplegia were of the spastic type, except for one flaccid-type paraplegia.

In the main, paraplegia is associated with disease of the thoracic spine. In 115 patients the thoracic area was involved; all of these patients had paraplegia. In six the cervical region was invaded; all of these had quadriplegia. In one instance the low lumbar region was involved with flaccid cauda equina type of paralysis.

The difficulties of accurate early diagnosis are well illustrated by the variety of diagnoses made elsewhere at onset of paraplegia. These included arthritis, fracture of the spine, neoplasm, myositis, gumma, ependymoma, amyotrophic lateral sclerosis, subacute combined degeneration of the cord, hysteria or other psychoneuroses, malingering, and sciatica. There were many other indefinite diagnoses, such as localized myositis with neurological manifestations, *et cetera*. By the time we received these patients correct diagnoses had finally been made.

Treatment Previous to Admission to Sea View Hospital

In twenty-five patients paraplegia developed while they were on the ward at Sea View Hospital and they were cared for throughout by us. Ninety-seven patients were admitted to us with paraplegia or paresis.

In six of these no treatment had been given. Ten had had casts, varying from jackets to double hip spicas. Thirty had had bed rest alone. One of these had had an aspiration of an abscess in the thoracic area of the spine. Six had been on Bradford frames. Four had been treated with active physical therapy. In twenty-one patients fusion had been done, but this was adequate in only two instances. The others either had had fusion of insufficient extent or pseudarthroses were present. Since the posterior elements were still intact for attachment, further spine fusion was possible and they were not hopeless cases. Many of them, however, were in desperate condition and operation was prevented by lesions other than those of the spine.

Bad as the above were, there were others admitted even more unfortunate. Fourteen had undergone laminectomy for paraplegia before admission to Sea View; only four of these patients survived. These four had their spine lesions stabilized by circumduction

fusion at Sea View. Those patients in whom the posterior elements had been removed by laminectomy all had had a fatal outcome before this method of circumduction fusion had been developed.

Two patients who were admitted after costotransversectomy had been done both died. Of four patients admitted with hemilaminectomy and fusion on the opposite side, two died and two had only partial recovery.

Treatment of Paraplegia at Sea View Hospital

At Sea View Hospital the whole concept of treatment for paraplegia associated with tuberculosis of the spine has been based on the pathological findings. Paraplegia in the main develops from extradural pressure from abscess formation. Small abscesses, tightly enclosed by normal ligamentous structures or firm fibrous walls, are the worst offenders. Large soft abscesses, which have escaped the natural restraining barriers, lose their ability to cause pressure and much less frequently are associated with paraplegia. Pressure from collapse and bone fragmentation is responsible for a minority of the cases. True transverse myelitis from pressure is unusual. We believed that 80 per cent. of patients with paraplegia associated with tuberculosis of the spine would recover after adequate surgical fusion and the recession of pressure which results. This belief has been confirmed by study of the series reported in this paper.

In 1934 anterior decompression (costotransversectomy and removal of sequestrated vertebral-body fragments) was done on five patients with paraplegia of three to fourteen years' duration, spine fusion for support having been done in advance. Despite prolonged pressure and complete paraplegia, all except one showed improvement after decompression. One patient recovered almost completely after paralysis of five years' duration. Another after fourteen years' complete paraplegia recovered 30 per cent. of function and was discharged as a wheel-chair patient. A third recovered almost completely three months after anterior decompression, his paraplegia having existed for three and one half years; but he died of meningitis six months after the operation. A fourth patient, whose paraplegia had existed for six years, began to move his right lower extremity at six months, and his left lower extremity at two years following decompression. His final recovery from a complete paraplegia was estimated at 30 per cent. A fifth patient who, after anterior decompression, had no recovery from paraplegia had a pseudarthrosis. An attempt at repair was made at the time of the decompression. Fusion never became solid at the site of pseudarthrosis and the patient finally signed herself out to another institution, still totally paralyzed.

We feel that costotransversectomy for simple decompression and without preceding fusion to prevent further collapse is inadvisable. It would be of only temporary benefit and adds the danger of wound breakdown and mixed infection, always present in surgical incision of a tuberculous lesion.

Reinforcing the impression that a solid spine fusion is essential to permanent recovery from paraplegia in tuberculous spine disease are five other patients in this series. They had spine fusions done, recovered from the paraplegia, and were discharged. All returned with paraplegia and a pseudarthrosis was found in all cases. After repair of the pseudarthrosis, recovery from paraplegia again resulted. In one of these patients paraplegia again developed and he was readmitted. A pseudarthrosis was found for the second time and was repaired. This time his fusion was explored before discharge and was found to be solid. Permanency of relief of paraplegia has resulted to date.

Two other patients in the series had recovered from paraplegia after enforced bed rest, only to have recurrence of the paraplegia when they became ambulatory again. Thereafter spine fusion was done and permanent relief of paraplegia resulted.

Fourteen patients were admitted to Sea View Hospital with laminectomy defects of

TABLE III

RECOVERIES

	No. of Patients	Per cent. of Group
Patients with paraplegia	122	
Hopeless cases in which no operation was performed	47	
Number of patients considered in study	75	
Patients surviving	53	70.66
Patients with complete recovery	33	44.00
Patients with partial recovery	13	17.33
Total of complete or partial recoveries	46	61.33

two to six segments. Of these, all are dead except four who have had circumduction fusions. In three of these treatment has been completed; these patients have been discharged and have resumed essentially normal activity. All have recovered from the paraplegia; this includes recovery of control of the bladder, bowel, and lower extremities. One has had completion of circumduction fusion and is ambulatory, but remains hospitalized.

In a study of the records of laminectomy procedures at other institutions from which these patients came, it is noteworthy that a number of patients improved considerably immediately after laminectomy, only to have the paraplegia recur within three months; they eventually died. From one institution on several occasions we have received patients with reports stating that hemilaminectomy had been done and that the surgeon considered it "very fortunate that only tuberculous disease was found". Therefore, a second procedure converting the hemilaminectomy into a total laminectomy had been performed to provide a more favorable outlook!

Even in the patients whom we have managed to save by circumduction fusion, tremendous surgical effort and hazard were necessary because of the laminectomy and the lack of posterior spinal elements for direct fusion fixation.

The concept of circumduction fusion was first developed in 1938[1-3] (Sea View Hospital Chart No. 17082, 1938) for cases inoperable because of tuberculous disease of the posterior elements with mixed infection. It has been used to by-pass the area of defect in these disastrous cases in which laminectomy had been performed.

Since with adequate spine fusion recovery from paraplegia remains permanent, and with laminectomy fatalities are inevitable, there would seem to be no choice between the two procedures for treatment of this condition.

Bed rest, high-caloric and high-protein diet, as well as streptomycin therapy, and all other forms of supportive treatment were used on these patients as soon as they became available. No plaster jackets or brace supports were used, either for the spine-fusion procedures or the circumduction fusions. No retention of the patients on Bradford frames, Stryker frames, or other supports was used. Firm mattress support with a fracture board beneath the mattress was routine.

As soon as streptomycin became available, it was used on these patients. It did not obviate the necessity of surgery or directly affect the paraplegia. This follow-up study was made before the advent of the isoniazids and iproniazids. In the past year we have checked the paraplegics under treatment with these chemicals and we have found that these drugs have had no direct effect on the paraplegia. Surgical fixation of the spine is still essential.

Deaths

Sixty-nine of 122 patients with paraplegia died at Sea View, a mortality of 56.55 per cent.

Forty-seven patients were estimated to have hopeless involvement on reception at

the Hospital and all of these died without surgery. Of the seventy-five whom we attempted to save, twenty-two died, a mortality rate of 29.3 per cent.

The causes of death in the twenty-two patients we attempted to save were as follows: six died of continued paraplegia associated with laminectomy, three of them with massive decubiti and three with breakdown of the incisional wounds of the laminectomy; six patients died with meningitis; five died of advancing pulmonary disease. Two succumbed with multiple osseous lesions and overwhelming tuberculous infection; two patients with posterior-element tuberculosis died of postoperative infection; one died with amyloidosis.

Recoveries

Of the 122 patients with paraplegia, forty-seven were in a hopeless condition and were never operated upon. Of the seventy-five we attempted to save, fifty-three survived, 70.66 per cent. Thirty-three with solid spine fusions recovered completely, 44 per cent.; three of these had circumduction fusions. Thirteen patients (17.33 per cent.) with solid spine fusions recovered with an estimated average of 62.75 per cent. normal function (Table III). Seven were unimproved as to paraplegia, but were discharged from Sea View, four in good condition with solid fusions and three against medical advice before solidity of fusion could be determined.

Of the seventy-five patients in desperate condition whom we attempted to save by surgery, forty-six (61.33 per cent.) recovered completely or to considerable extent.

CONCLUSIONS

1. Laminectomy has no place in the treatment of paraplegia associated with tuberculous disease of the spine. Spine fusion is essential.

2. In the patients at Sea View Hospital paraplegia was of serious import. In such cases there was a mortality rate of 56.55 per cent.

3. Of 122 patients with this condition, fifty-three survived. No patient survived who d d not have a solid spine fusion. Of the survivors 62.26 per cent. recovered completely, 24.53 per cent. recovered to a considerable extent, and 13.21 per cent. showed no improvement in their paraplegia.

4. Circumduction fusion and the advent of streptomycin have remarkably improved the outlook.

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A STUDY OF THE ACTION AT VARYING LENGTHS OF TWO MUSCLES OF OPPOSING FUNCTION, TIBIALIS ANTERIOR AND GASTROCNEMIUS, IN THE RAT

A Preliminary Report

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It is usual to think of all muscles as acting the same and having similar physiological properties. It is possible that structure may result in differences in muscle function. In this paper the tibialis anterior and gastrocnemius of the rat are compared. When these muscles were tested by means of successive isometric contractions at steadily increasing lengths, it became apparent that there may be a fundamental difference in muscle action at similar points on a length-tension curve.

Resting tension is the tension existing in the muscle at the time of stimulation; developed tension is the tension produced as the result of the stimulus. It is evident that an increase in the length of a muscle will result in an increase in its resting tension. The point at which the muscle first shows tension independent of stimulation is defined as initial resting length.

The point at which the maximum developed tension appeared was found with a low resting tension in the case of tibialis anterior. The gastrocnemius apparently needs considerable increase in length, and therefore in resting tension, in order to achieve maximum developed tension.

HISTORICAL REVIEW

Some doubt of Galen's original view that muscle contractions are the result of the flowing of animal spirits into the muscle was expressed by Francis Glisson (1597 to 1677). He contended that if this were true the muscle should increase in volume with activity. He had a muscular person place his arm in a glass tube filled with water and noted that on contraction the volume, if anything, tended to diminish. Steno, or Stenson, in the same era, in Denmark, thought that there could be primarily "tension muscles",—that is, those with pennate fibers, in which the maximum tension would be developed only on very little shortening. Developed tension according to Steno was the result of individual forces of the fibers comprising the muscle.

In 1715 Leeuwenhoek recognized the transverse striations of skeletal muscle and the existence of a fiber sheath. Robert Whytt in England wrote, "The motions occasioned by stretching the fibres of any muscle will be greater or less as the muscle is more or less stretched. . . ." The proof by Galvani of a potential difference in living tissues and the work of Volta with dissimilar metals laid the groundwork for the testing of many of these fundamental concepts.

Gotch suggested that muscle activity was graded through a variation in the number of contractile units in activity at any one time, rather than the size of the nerve impulse. Keith Lucas found that, once all fibers were in activity, further increase of a gradually intensified stimulus did not augment the response. Skeletal muscle fibers are isolated from each other and do not contract *en masse*. If a fiber contracts at all, it contracts maximally; but the total response of the muscle in producing a maximum contraction will vary with the mechanical and electrical state of the muscle, its past activity, and its length.

That part of the study of muscle physiology dealing with function was given impetus by Blix who noted the importance of initial length on the magnitude of the contraction.

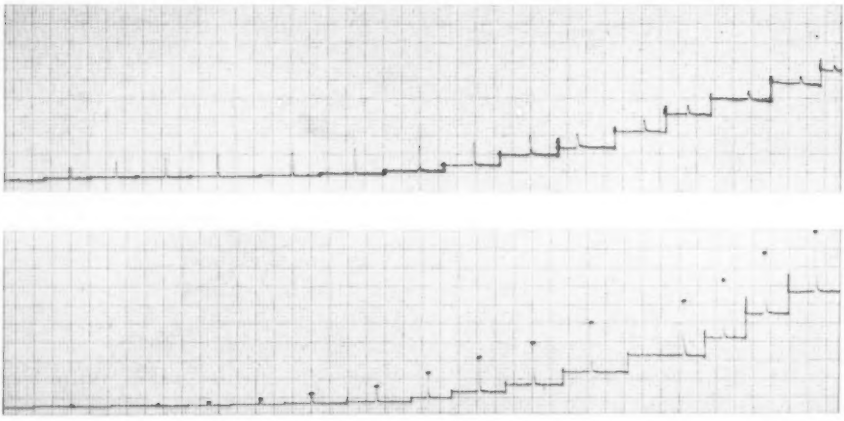

CHART I

Baldwin-Sanborn strain-gauge recording of data from the tibialis anterior (at the top) and gastrocnemius (at the bottom) of the rat. Each large division represents 200 grams and each small division, 40 grams. Between each contraction, the machine was stopped and the muscle was increased 0.1 centimeter in length; the resultant increase in tension is shown. The reduction in resting tension prior to stimulus and contraction was due to the viscosity of the muscle. The recording begins at the point where resting tension first became evident in the muscle. The top of the contractions in the tracing from the gastrocnemius has been marked for clarity in reproduction.

He produced length-tension curves with the gastrocnemius of the frog. In 1914, Evans and Hill observed that developed tension rises to a maximum as the resting length is increased and then decreases as the length is raised still further.

Fulton gave the following figures for initial tension and developed tension as related to the gastrocnemius of a frog. It was noted that the duration of the twitch increased with increases in length.

Initial Tension	*Developed Tension*
5	210
15	235
25	385
40	390
55	415
70	410
100	420
130	430

METHOD

Albino rats, male and female, weighing 200 to 300 grams, were anaesthetized with ether. An incision for the tibialis anterior and one for the gastrocnemius tendon were made. A third incision through the posterior portion of the thigh exposed the sciatic nerve, which was run through an electrode consisting of two platinum wire rings. A Grass stimulator was used, putting out a square-wave stimulus of one-millisecond duration. The supramaximal stimulus was determined on each muscle and ranged from 0.5 to 8 volts at one millisecond.

The rat was placed on a heavy steel device which held it by means of a pelvic pin and a foot tie. A strain gauge was mounted on a moving section which could accurately

Chart II (*See page 743*): The relation of developed tension to resting tension in the gastrocnemius and tibialis anterior of the rat is compared. The curves are taken from a representative run for each muscle. Each gradation represents 100 grams. The early rise in the developed-tension curve for the tibialis anterior in relation to the resting tension is in contrast to the gastrocnemius.

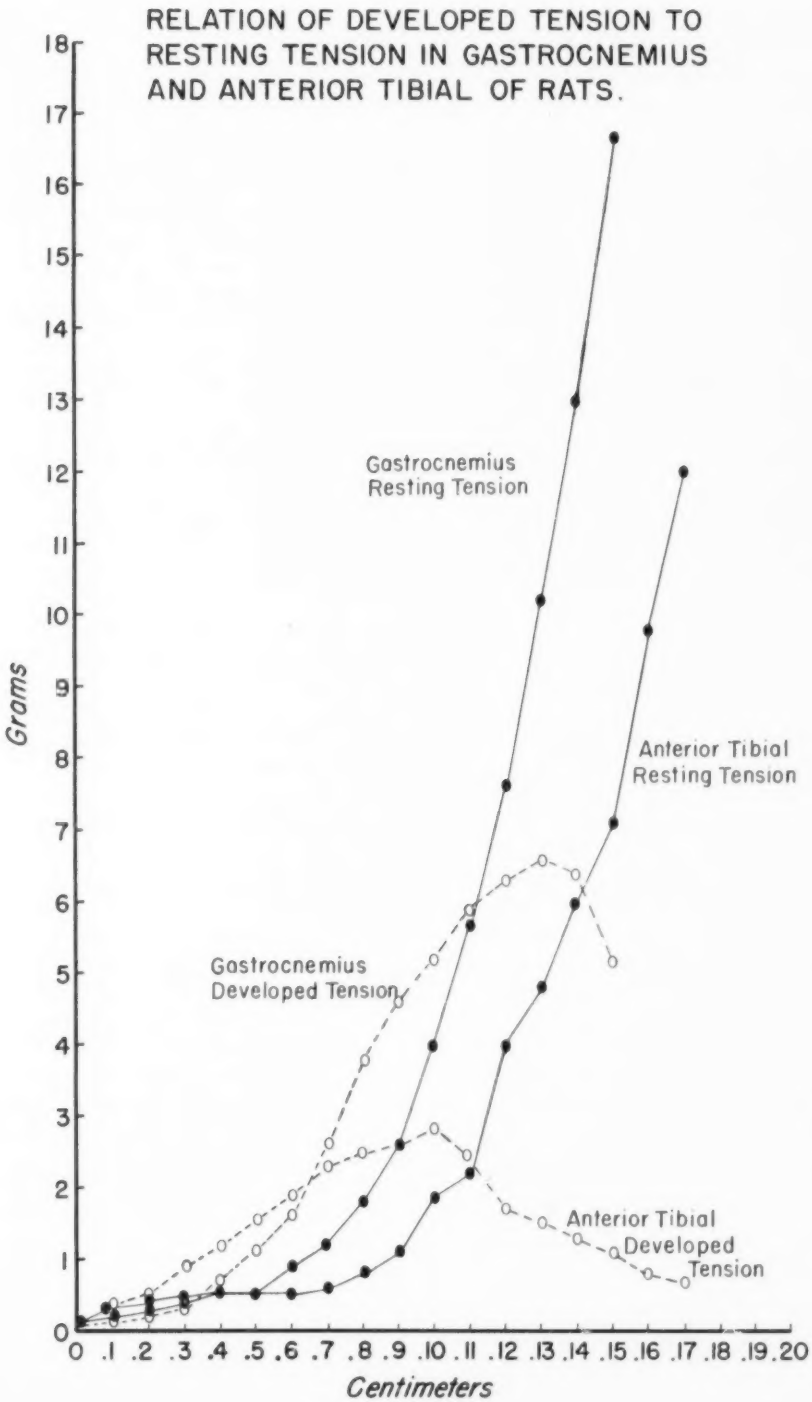
RELATION OF DEVELOPED TENSION TO RESTING TENSION IN GASTROCNEMIUS AND ANTERIOR TIBIAL OF RATS.
Grams
Centimeters
Gastrocnemius Resting Tension
Anterior Tibial Resting Tension
Gastrocnemius Developed Tension
Anterior Tibial Developed Tension
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 .10 .11 .12 .13 .14 .15 .16 .17 .18 .19 .20

CHART II (*See page 742*)

change the length of the muscle attached to the strain gauge by means of a screw. The tendon was placed in a heavy clamp attached to a wire loop so that the muscle pull was always in the same relation to the gauge.

The point just at the development of resting tension in the muscle was determined and was called resting length. This was the point of initial stimulation and thereafter the muscle was stimulated at increases of 0.1 centimeter in length. Thus, on the same recording, one could obtain the exact resting tension and developed tension with stimulation.

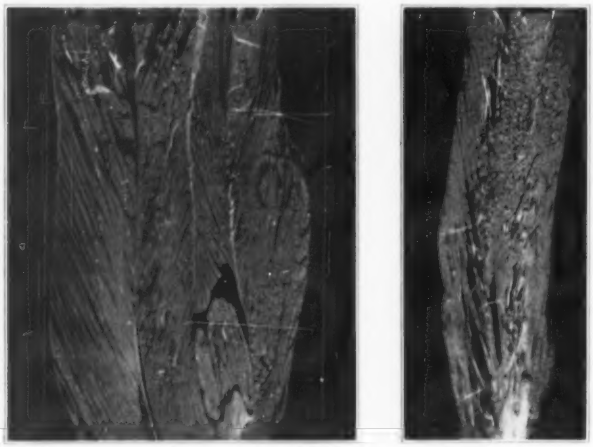

FIG. 1

Direct-contact print of a slide of a gastrocnemius (left) and a tibialis anterior (right). The muscles were cut on a coronal plane. The interlacing, more complicated structure of the gastrocnemius is shown as compared to the simpler structure of the tibialis anterior.

RESULTS

For the purposes of this study, the experiment was done on a total of twenty-five muscles in ten rats. The tibialis anterior was run fifteen times; the gastrocnemius, ten. There was considerable variation in the tension generated when one muscle was compared with another. The shape of the resting-tension curve was the same in general form. However, an important difference was noted in the location and development of the developed-tension curve when the tibialis anterior and gastrocnemius muscles were compared.

The developed tension of the tibialis anterior muscle in the rat always rose to a maximum on the left-hand side of the resting-tension curve. The gastrocnemius muscle, on the other hand, developed increasing heights of tension very slowly, so that the maximum was reached well to the right of its resting-tension curve. The ascent of the developed-tension curve was more gradual. It was evident that very little tension was required for the tibialis anterior to perform maximally but that considerable tension was needed for the gastrocnemius. In terms of length, the tibialis anterior performed at maximum tension just beyond its initial resting length, while the gastrocnemius worked at maximum developed tension when its length and, correspondingly, its resting tension had been considerably increased. The average increase in length required by the tibialis anterior was .76 centimeter, while the average for the gastrocnemius was 1.22 centimeters (approximately 35 to 45 per cent. of the total length for each). It was also noted that the resting-tension curve of the tibialis anterior tended to develop slightly more slowly with increasing length than that of the gastrocnemius which tended to increase relatively rapidly, although they maintained the same general shape.

DISCUSSION

Certain differences have been noted in the past in the physiological action of muscles of different structures. In a diagonally fibered muscle, a given increase in length causes an unequal alteration in the length of the constituent fibers. In the muscles of many animals, red and white fibers may co-exist. The action-current of red-fibered muscle may be four times as long as the duration in white fibers. The diphasic recording of muscle-action currents may vary between parallel and diagonally fibered muscle.

The gastrocnemius is a complex muscle working through two joints with great power required of it, particularly so when under tension. The tibialis anterior has a simpler function with its primary use at shorter lengths. The complex fiber arrangement of the gastrocnemius of a rat can be readily compared with the simple fiber arrangement in the tibialis anterior by cutting each muscle in a plane in its long axis.

The anatomical configuration and nature of the muscle function were brought out by the differences in the length-tension diagram of the two muscles. This observation may be of some importance in our understanding of fundamental muscle action and would enter into our conception of muscle transplantations. The action of the hamstring muscles, when they are transferred forward to the patella, which exert maximum power in extending the knee when the hip is flexed, may well be explained on this basis. However, there is no evidence at the present time that this observation applies to human muscle.

CONCLUSIONS

The length-tension diagram for the tibialis anterior and gastrocnemius muscles of the rat reveals differences in the range of maximum developed tension in relation to the resting tension of the muscle at the time of stimulation. It is felt that the standard configuration noted by Blix in the gastrocnemius of the frog cannot be applied to all length-tension diagrams and that the point of maximum developed tension of a muscle will vary with structure and function.

REFERENCE

FULTON, J. F.: Muscular Contraction and the Reflex Control of Movement. Chap. I and pp. 151 and 153. Baltimore, The Williams and Wilkins Company, 1926.

IMPROVED TYPE OF HIP-DISARTICULATION PROSTHESIS*

BY CHARLES G. HUTTER, M.D., *Veterans Administration*

From the Veterans Administration Regional Office, Los Angeles, California

An improved type of prosthesis for the amputee with a disarticulation at the hip joint has been fitted to eight patients. The increased comfort and satisfaction of the amputee with this type of artificial limb has been such that we are no longer fitting hip-joint amputees with the tilting-table type of prosthesis.

For want of more adequate terminology, the limb has been termed a "saucer" type of above-the-knee prosthesis. It is so called because the weight is borne on the top of the limb in a concavity which resembles a saucer in shape and size. The ischial tuberosity fits into this concavity of the limb and supports the body weight in exactly the same manner as when the patient is seated without the prosthesis. The limb is secured to the patient by means of a pelvic belt, which eliminates the pelvic bucket, the shoulder straps, and the bulkiness of the tilting-table limb (Fig. 1).

Although the prosthesis appears to be very much like the conventional limb for the above-the-knee amputee, certain special adaptations are necessary for the successful functioning of this limb. In the fabrication of these limbs, we have found that, when a friction type of knee joint is employed, it is necessary to introduce a spring lock on the pelvic joint. In some cases, however, we have been able to replace the pelvic lock with a free joint which

* Reviewed in the Veterans Administration and published with the approval of the Chief Medical Director. The statements and conclusions published by the author are the result of his own study and do not necessarily reflect the opinion and policy of the Veterans Administration.

FIG. 1

The photographs show the fit and shape of the saucer type of hip-disarticulation prosthesis.

has a stop to prevent hyperextension of the hip joint. This has been made possible by employing a knee joint which locks automatically in extension when the heel is in contact with the floor.

The knee joint locks automatically when the weight is borne on the heel. There is a cord between the heel and the knee which activates the locking device (Fig. 2). As the body weight is carried onto the toe of the prosthesis, the knee lock is released and flexion of the knee ensues. This stability of the knee joint of the prosthesis is very important to the amputee lacking hip-joint control.

In order to control the saucer type of limb with a free pelvic hinge or hip joint, it is necessary that the pelvic band fit quite securely around the pelvis. The pelvic band is made of steel; it is so constructed that about one third of the pelvis is encircled by the steel, the two prongs extending anteriorly and posteriorly. The remainder of the pelvic band is made of heavy saddle leather, padded with felt on the body side. When this belt has been firmly secured about the pelvis below the iliac crests, a snug, secure fixation of the limb to the pelvis is possible.

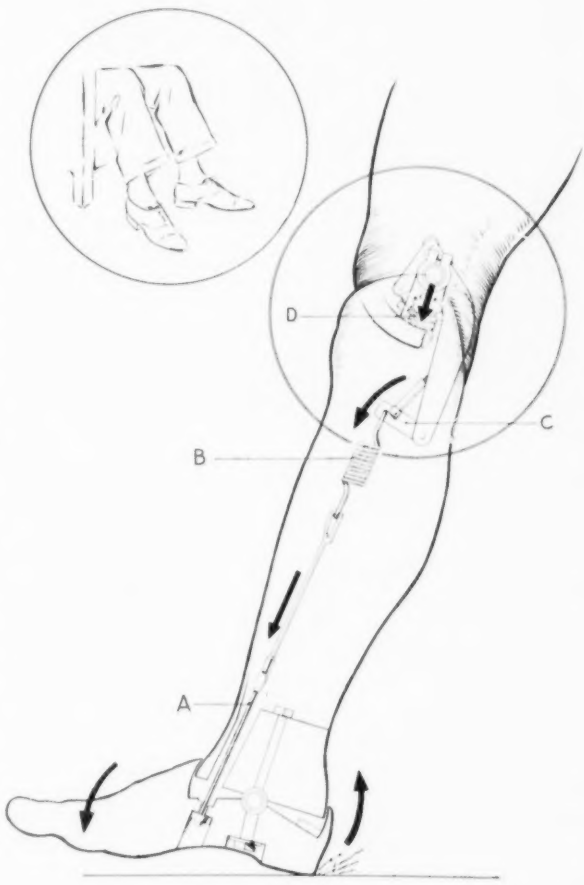

FIG. 2

The diagram shows the self-locking knee mechanism: *A*, actuating connection with the foot; *B*, spring; *C*, lever arm; and *D*, cam lock on the knee bolt (Courtesy of L. L. Mortensen).

In one case, the patient had had complete resection of the gluteal muscles and the tensor fasciae femoris from the ilium. He had suffered from osteomyelitis of the pelvic bone, and the skin which covered the bone was scarred and thin, and its circulation was poor. In this case, it was necessary to provide a wide pelvic band, heavily padded with sponge rubber, in order to prevent breakdown of the skin.

The saucer-shaped socket is hollowed out of the thigh portion of the limb. The socket and thigh portion are usually made of willow wood. The socket is then padded with firm sponge rubber and covered with leather which has been treated with nylon to prevent the absorption of perspiration. We have tried making the socket out of padding which rests upon a rawhide lacing across the lumen of the hollow thigh portion of the limb, but this has not been satisfactory and has been discontinued.

One of the amputees was unable to drive his automobile because the limited abduc-

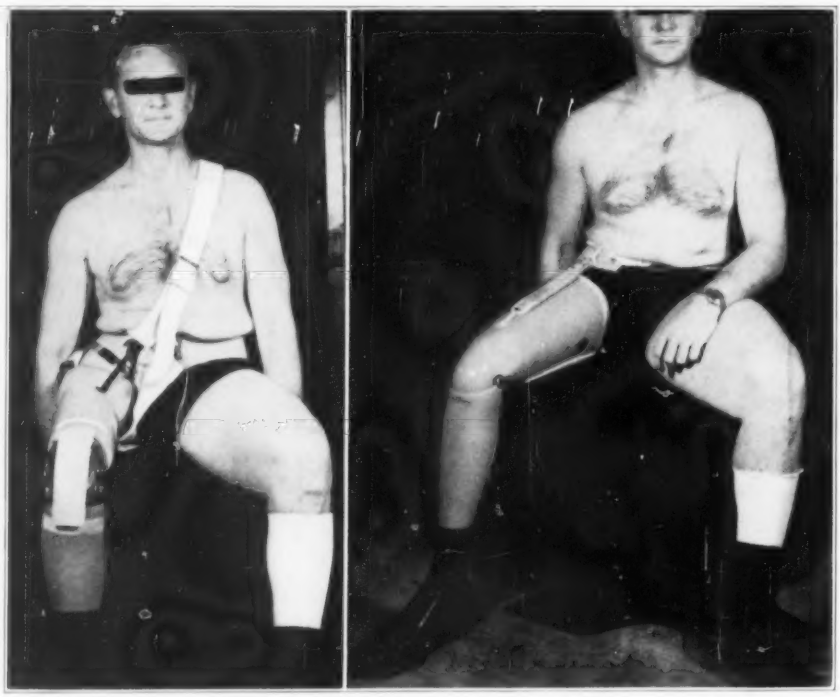

FIG. 3

In the photographs, the conventional tilting-table prosthesis is compared with the saucer type of prosthesis with the patient sitting. Note the ease of abduction with the saucer type of prosthesis.

tion of the tilting-table type of prosthesis prevented him from placing the limb beneath the steering wheel of his car. The steering wheel is designed so that it fits between the abducted limbs of the driver; in this patient's case, sufficient abduction was impossible. With the saucer type of prosthesis, however, he has been able to drive his car, and he states that he is again able to sit with comfort.

When seated, the amputee with the saucer type of prosthesis is completely free of the ischial seat. He sits in the same manner as he would without any prosthesis whatsoever—a position most comfortable for any amputee (Fig. 3).

For a stump sock, we have found that the knitted-to-measure trunks of wool which cover the stump are most satisfactory. These are suitable for cold-weather wear, while an undershort made of knitted cotton, in which one leg is closed or sewed together, is satisfactory for summer wear. Several of the men have found it more satisfactory to wear a long T-shirt, one half of the lower end of which is closed on one side. This closed portion fits beneath the pelvis on the side of the amputation, and thus provides a suitable interposing cotton surface between the stump and the top of the prosthesis. Lately, most of the amputees have utilized the T-shirt method of protection of the stump because of the ease of laundering the T-shirt.

Of the eight patients fitted with the saucer type of prosthesis, six had previously worn the tilting-table prosthesis. In each case, the patient has been satisfied with the new type of prosthesis, and has declared upon repeated occasions that the increased comfort and the ease with which he is able to walk with this prosthesis make it highly desirable and much more suitable than the conventional tilting-table prosthesis. We feel that a hip-disarticulation amputation is no longer an indication for a tilting-table prosthesis.

SCREW STABILIZATION IN FRACTURES OF THE TIBIAL SHAFT

BY EDGAR H. WHITE, M.D., THOMAS J. RADLEY, M.D.,
AND NEAL N. EARLEY, M.D., CINCINNATI, OHIO

In recent years numerous articles have been written concerning the compression factor in the healing of fractures, particularly of shaft fractures in the long bones. Compression to an extreme degree results in bone atrophy with inadequate osteogenesis, but recently the value of moderate compression has been emphasized as a desirable and important factor in promoting fracture repair. Employment of metallic plates of the Lane and Sherman type in the internal fixation of unstable fractures of long bones has frequently resulted in the distraction of fragments, with subsequent delayed union or established non-union. The local hyperaemia present at the fracture level produces absorption of calcium salts and matrix; therefore, the necessity for the bone fragments to approximate each other with obliteration of the gap is primary and fundamental in the development of prompt union. The decrease in complications which has been noted following the employment of slotted plates, which permit compression and which do not maintain the fragments speared in distraction, is based upon this physiological principle.

The employment of a long metallic plate with a minimum of four screws entails the insertion of considerable foreign material. This technique is particularly hazardous when the primary fixation of unstable compound fractures is carried out at the time of débridement of the soft-tissue defect. It has long been axiomatic that the simpler the method, provided it is adequate, the more satisfactory the end result in most instances. It is agreed that the insertion of metal in compound fractures should be held to a minimum at the time of the original débridement and closure. Any method requiring the insertion of appreciably less foreign material is obviously advantageous and desirable. Metallic screws alone as the stabilizing factor have proved to be highly satisfactory in our hands. We have been impressed with the satisfactory results of immediate internal fixation in suitable compound fractures when treatment of the fracture is begun simultaneously with that of the soft-tissue injury. The practice of delaying the definitive reduction of the fracture fragments until after the original compound injury has been converted to a closed fracture by suitable soft-tissue surgery with subsequent healing of the soft tissues has been avoided as often as feasible. Experience has proved, particularly in fractures of the shaft of the tibia, that adequate stabilization is often obtained by a single screw or at the most two to three screws. The advantages of using appreciably less foreign material than the orthodox plate together with multiple screws have been apparent. In our hands the stabilization of shaft fractures by screw fixation has been a simple and satisfactory procedure. Slotted plates of the Eggers type have been employed occasionally in extremely comminuted fractures in which complete bridging of the comminuted area was necessary for adequate fixation. Segmental fractures, in which the middle fragment was fixed at only one end by a screw, were often satisfactorily reduced and the reduction was maintained without insertion of additional metal at the second fracture level.

The introduction of intramedullary-pin fixation for fractures of the shaft of the femur, the hanging cast for fractures of the shaft of the humerus, and intramedullary wires for fractures of the radius and ulna have relegated screw fixation as a method of treatment almost entirely to shaft fractures of the tibia. There is only rarely an indication for employment of slotted plates in fractures of the forearm or humerus; stabilization of shaft fractures of metacarpals or metatarsals by plates or screws is seldom indicated. While we believe that the method described is an extremely simple procedure, which has been routinely employed by a resident staff in training, there are several salient principles which must be observed.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Closed segmental fractures received in an automobile accident.
Fig. 1-B: Stabilization at both fracture levels was obtained by a single screw. Four months after injury there was anatomical alignment and healing was well established.

This report comprises sixty-six cases of unstable fractures of the shaft of the tibia and fibula in which adequate reduction could not be maintained by the usual closed manipulation and immobilization in a cast. The cases were unselected and represented serial admissions in a large general hospital.

RESULTS

Excellent Results

Number of patients	44
Average age	38.6 years
Closed fractures	36
Compound fractures	8
Length of time in plaster	20 weeks
Length of time between injury and surgery	8.4 days

A result was judged to be *excellent* when healing occurred after primary reduction with anatomical position of the fragments and when sufficient callus was established so that all external immobilization could be discarded within four to six months from the time of surgery. An end result was classified as *good* when there was prompt union of the fracture but with a few degrees of angulation, not exceeding 10 degrees in either the anteroposterior or the lateral plane. A result was considered *poor* when infection was established, when union occurred with over 10 degrees of angulation, or when non-union persisted.

The delay of 8.4 days between injury and surgery was occasioned by complicated injuries such as cerebral contusion or skull fractures, as well as thoracic and abdominal injuries which prevented immediate definitive surgery.

Good Results

Number of patients	7
Average age	30.2 years
Closed fractures	6
Compound fractures	1
Length of time in plaster	25.5 weeks
Length of time between injury and surgery	3.1 days

An analysis of the good results may not be so instructive as a careful survey of the cases in which results were unsatisfactory. With few exceptions, surgery was carried out by the resident staff in the process of training, and analysis reveals that more than half of the poor results were due not to the method employed but to errors in technique and judgment.

It was soon recognized that the employment of three or more screws across a single fracture line, even when marked comminution was present, was a definite distracting element which would not permit compression and apposition of the fragments with closure of the absorption gap. Therefore, in the majority of cases in this series only one or two screws were employed. The decision as to when to

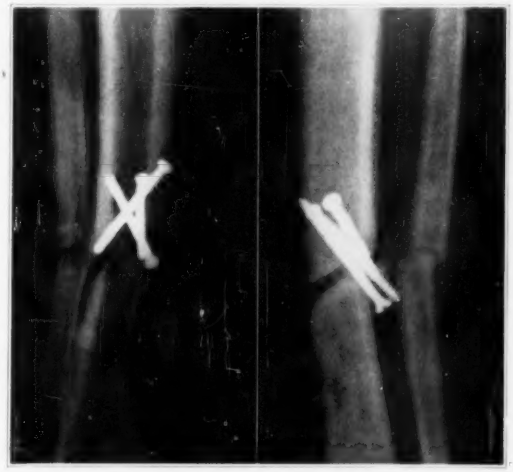

FIG. 2

Fig. 2: Fixation of an unstable fracture by multiple screws resulted in distraction of the fragments and non-union. The fracture probably could have been stabilized by a single screw appropriately placed.

Fig. 3-A: Roentgenograms showing a markedly comminuted, closed fracture. Such fractures are usually difficult to treat by means of a slotted plate, because of the curve of the tibia and because fixation must be through cancellous bone, which prevents adequate fixation by plate immediately proximal to ankle joint.

Fig. 3-B: Roentgenograms made after reduction, showing anatomical position and early union of the fragments with stabilization by a minimal amount of metal.

FIG. 3-A

FIG. 3-B

carry out delayed open reduction with internal fixation of a severe or grossly contaminated compound fracture after soft-tissue healing is still a most difficult one to make, even with the advantage of efficient antibiotics. Two thirds of our poor results were due to too early operative intervention with insertion of metallic fixation, even though this was done after the cessation of all drainage and after healing of the soft tissues. The use of numerous screws, the failure to engage the opposite cortex adequately, the rough application of the cast after surgery, and the wedging of the cast to correct minor degrees of angulation before some evidence of uncalcified callus was present were factors responsible for some of our cases of non-union. In a total of fifty-nine cases in which competent surgery and post-operative care had been employed, excluding all cases of compound fractures in which secondary surgery had been performed too soon, there were only four instances of established non-union.

Poor Results

Number of patients	11
Average age	42.5
Closed fractures	7
Compound fractures	4
Length of time between injury and surgery	14.5 days
Sliding bone grafts with union	6
Multiple bone-grafting procedures with union	1
Patients still have wide osseous defect with non-union, undergoing plastic surgery	2
Union with osteomyelitis; sequestrectomy carried out, with cessation of drainage	1
Union despite inadequate fixation	1

Until more satisfactory methods of intramedullary nailing of unstable fractures of the tibia are developed which will overcome the present inevitable posterior bowing, this simple and efficient method has been found to be the most effective. The small amount of metal employed makes it particularly suitable for selected compound fractures in which the fracture treatment can be instituted at the time of the original débridement.

While this method is not applicable in extremely comminuted fractures of the shaft of the tibia, cases in which slotted or compression plates are required are exceptional and we believe that the slotted-plate method of treatment should be limited to relatively few instances. In no instance has it been necessary to remove the screws because of pain. In four cases screws had to be removed for persistent or recurrent drainage.

Errors in Surgical Judgment: Three Cases

Compound fractures	3
Débridement and closure of compound wound on same day with *per primam* healing of soft tissues	3
Average length of time between original débridement and operative fixation of fracture fragments	41 days
Union	1
Chronic osteomyelitis	3

METHOD

Employment of the pneumatic tourniquet is a valuable adjunct, but it is no guarantee against failure. While some operators have an arbitrary rule not to employ a tourniquet in patients over fifty, we feel that the simplicity of this procedure, which rarely entails more than sixty to seventy-five minutes of tourniquet time, permits greater leeway; the tourniquet has been used on the majority of our patients. After the leg has been shaved, the extremity is emptied of all blood, as far as possible, by the application of a three-inch rubber Martin bandage; the tourniquet is then inflated to 300 millimeters of mercury. The operative site is scrubbed for five minutes with cetyl pyridinium chloride while the operator is scrubbing. This technique entails an additional few minutes of tourniquet time, but it is justified by the presence of a more completely avascular field and greater sterility than results from the method in which the leg is scrubbed first and wrapped in sterile towels, and the rubber bandage is applied over the towels.

The operative approach, the elevation of suitable flaps without layering, and the reduction of the fracture are routine. Drill holes are then fashioned by means of the electric bone drill, which is placed at right angles to the cortex of the fragments. The selection of the electric rather than the hand drill is an extremely important point, inasmuch as quite often the drill must penetrate heavy cortical bone and the breaking of drills may be an annoying occurrence. The employment of the electric drill permits selection of the correct site, regardless of the thickness of the cortical bone, and materially reduces operative time. The insertion of a single screw across the fracture site results in surprising stability in many cases. If considerable mobility at the fracture level is still present, a second or third screw is inserted, but this has been found to be necessary only in extremely comminuted or in segmental fractures. The recent paper by Arzimanoglou and Skiadaressis [1] would indicate that the greatest stability is obtained when in-

FIG. 4

Fig. 4: Unstable oblique fractures of the tibia and fibula with fixation by a single screw. This type of stabilization represents the method of fixation used in the majority of cases in this series. The alignment is anatomical, with a minimum of metallic fixation.

Fig. 5: Illustrating stabilization of oblique fractures in an unsatisfactory position. The anteroposterior view would indicate engagement of both fragments by screw fixation, but close inspection of the lateral projection reveals that the distal fragment has not been engaged by either screw.

Fig. 6: Wedging revealed satisfactory correction of malposition in the anteroposterior and lateral views, but obviously there was no engagement of the distal fragment. Further slipping and overriding occurred and eventually stabilization by a sliding bone graft became necessary. This case represents an error in technique rather than in the method employed.

FIG. 5

FIG. 6

sertion of the screws is at right angles to the cortex, regardless of the obliquity of the fracture. The stabilization of the major fracture fragments is not so complete as that obtained after insertion of a plate with multiple screws, but it is not necessary that stabilization be so complete that the entire leg can be carelessly picked up. We are satisfied if the distal tibial fragment can be carefully raised, and the entire leg will then follow in one unit with no appreciable change in the relative position of the fragments.

The selection of the electric drill is paramount only to the careful application of the cast. After closure of the surgical incision, a toe-to-groin padded cast is applied, with several important precautions. The patient's hips are moved toward the side of the involved leg and the lower extremity is then carefully brought over the side of the table, so that the knee is allowed to flex to a right angle. A toe-to-knee cast is applied, with the leg in a completely dependent position. After the plaster has dried so that the tamponade element is adequate, the leg is elevated, the tourniquet is released, and the remainder of the cast is applied. If the cast has been carelessly applied by an inexperienced operator, so that loss of the anatomical reduction results, or if the fracture has been stabilized with angulation, it has been our practice to wedge the cast four to six weeks after surgery. This has been an efficient means of correcting minimal malalignment; in no instance where adequate engagement of the distal cortex has been present has displacement occurred. A window is cut in the cast four days after surgery and the suture line is inspected. The removal of blood-soaked dressings at this time prevents maceration; herniation of soft tissues through the window has not been troublesome.

COMMENT

This study is based upon sixty-six consecutive cases of unstable fractures of the shaft of the tibia with accompanying fractures of the fibula. Lack of adequate follow-up excluded four cases from this series. Forty-four cases were judged to represent excellent results, seven were classified as good, and eleven as fair to poor. Thus 82.2 per cent. of all patients could be classified as having a satisfactory end result.

Only four of the eleven poor results could be classified as failures directly attributable to the method employed. Three of the four cases were closed fractures and in no instance did slipping occur. Non-union occurred in all four cases and bone-grafting procedures were necessary to obtain union. Of the remaining seven patients classified as having unsatisfactory results, four are so classified because of inadequate primary surgery. In two instances the screw failed to engage the opposite cortex of the second fragment. In a large teaching institution, where most of the surgery is carried out by the resident staff in training, certain errors in technique are inevitable and these failures cannot be attributed to the method selected.

As has long been realized, the most difficult decision, requiring the utmost in mature judgment, is the determination of the time for internal fixation of a compound fracture after healing of the soft-tissue defect.

Our experience corroborates that in previous reports, in which the most disabling failures, with the longest period of disability, occurred in those instances of compound fractures in which internal fixation of the unreduced fragments had been carried out too soon after the healing of the overlying tissues. More effective antibiotics have made the orthopaedic surgeon bolder in instituting earlier stabilization of compound fractures after healing of the laceration and cessation of all drainage. The interval of six months between healing and operative attack upon bone generally accepted as necessary has been materially shortened and, at the present time, four to six weeks are judged to be adequate in most instances.

Despite the satisfactory results obtained in the majority of compound fractures in which open reduction was instituted secondarily, we have had three instances of extremely poor end results, because internal fixation had been done too soon after the healing of the

skin defect. Union was obtained in one of the three patients, but with chronic osteomyelitis and drainage. The remaining two patients have had multiple surgical procedures with long periods of hospitalization and disability. Obviously these three poor results cannot be attributed primarily to the method employed, but are attributable to errors in surgical judgment. When the four cases of poor surgical technique are added to the above three cases, it is apparent that in only four cases out of fifty-five were unsatisfactory results directly due to the therapy employed. This represents 7.27 per cent. of unsatisfactory results, which is certainly gratifyingly small.

1. Arzimanoglou, Anthony, and Skiaderessis, George: Study of Internal Fixation by Screws of Oblique Fractures in Long Bones. J. Bone and Joint Surg., **34-A:** 219–223, Jan. 1952.

OLD SUBLUXATION OF THE KNEE

BY HARRY WINKLER, M.D., CHARLOTTE, NORTH CAROLINA

A diligent search of the literature on the specific treatment of old, chronic subluxation of the knee joint has failed to reveal a description of a lesion similar to that presented in this article.

Dislocation and subluxation of the knee are relatively rare. Most textbooks describe an anterior, a posterior, and a lateral dislocation. Treatment usually recommended for the acute dislocation is manipulation and reduction under anaesthesia and immobilization in a cast for a reasonable length of time, followed by a suitable program of physical therapy. The old unreduced type offers, of course, a very poor prognosis as regards joint function and will usually require fusion. It is quite likely that, if the subluxation to be described had been completely reduced and the joint had been immobilized for a sufficiently long period of time, no such clinical picture as that here presented would have occurred.

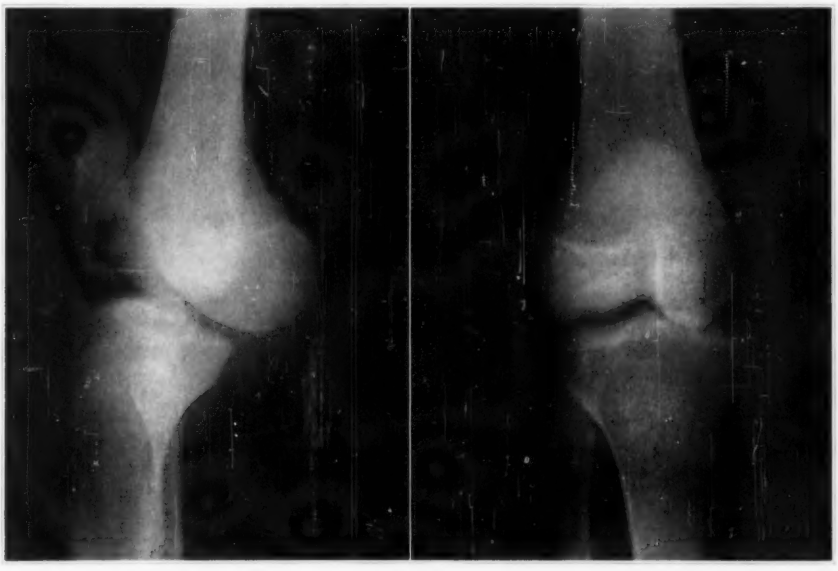

Fig. 1

Roentgenogram, June 16, 1950, showing old dislocation of right knee.

Miss D. R., an eighteen-year-old white woman, was referred for treatment on June 16, 1950. On November 15, 1949, while standing on the side of the road waiting for a bus, she had been struck by an automobile. She was taken immediately to a hospital in a neighboring community, where fracture of the left femur, fracture of the left tibia and fibula, and dislocation of the right knee were noted. Approximately two weeks after her admission, the fracture of the left femur was reduced and immobilized by means of external skeletal fixation. A fracture of the middle third of the tibia was immobilized by transverse Steinmann pins above and below the fracture site and the leg and thigh were incorporated in a plaster cast. The dislocation of the right knee was treated by immobilization and a plaster cast for approximately one month. The patient was kept in the hospital until March 31, 1950. The external skeletal fixation in the femur had been removed in the middle of March 1950; at that time union had seemed to be quite firm. Later roentgenograms, however, revealed a non-union of the tibial fracture.

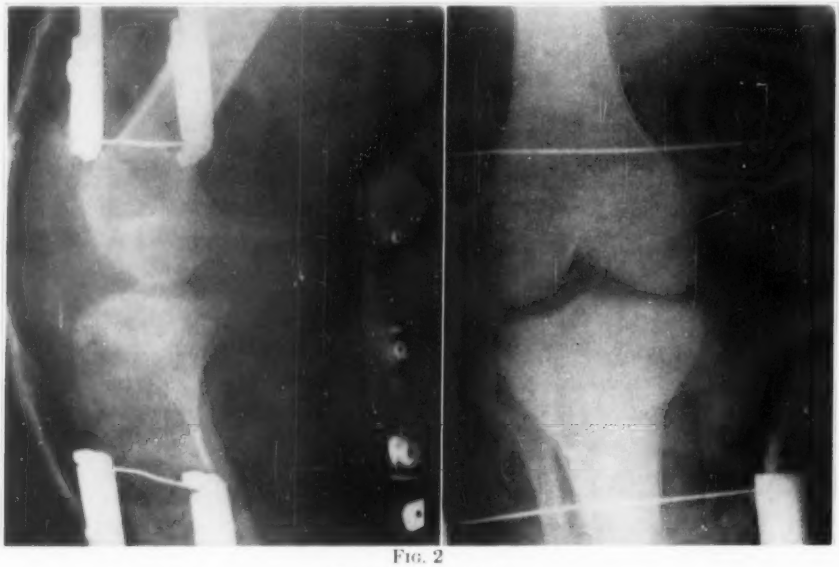

FIG. 2
September 21, 1951.

The patient was admitted to the Charlotte Memorial Hospital on June 28, 1950. The left leg from the knee to the toes was encased in a plaster cast in which were incorporated transverse Steinmann pins, one just below the tibial tubercle and the other just above the ankle.

In the right lower extremity, marked limitation of motion was noted in the knee, the range being from 180 to 165 degrees. The patella appeared to be in normal position, approximately one inch above the knee joint. The left lower extremity revealed marked restriction of motion in the knee, the range being from 180 to 150 degrees.

The fracture of the left femur was found to be healed, but there was non-union in the left tibia and an old dislocation of the right knee, with marked limitation of motion and partial subluxation, the tibia being displaced anteriorly and medially (Fig. 1).

A sliding bone graft was placed in the left tibia across the fracture on June 29, 1950. Nothing was done about the subluxation of the right knee in view of the non-union of the left tibia; moreover, the patient was unwilling to have anything done to the right knee at this time.

Union of the bone graft and the host bone on the left was delayed, although the patient was ambulatory, first with a walking cast and later without protection. The patient continued to be averse to procedures suggested for the right knee when seen on December 8, 1950. She was not seen again until May 14, 1951, when roentgenograms failed to show solid union in the tibia in which bone-grafting had been done, but we felt that surgery for the right knee could be attempted at any time.

On September 3, 1951, the patient was readmitted to the Hospital and on September 4, 1951, operation on the right knee was performed. A pneumatic tourniquet was applied to the upper portion of the right thigh. A utility type of incision was employed across the medial aspect of the knee joint. Upon exposure, the joint was found to be filled with scar tissue. Both of the menisci were defined and resected, as well as the scar tissue. The cruciate ligaments were not seen or defined.

The cartilage over both the tibial and the femoral condyles was atrophic in appearance and there were changes over the distal end of the femur, where pressure from the tibia had produced a pseudo-articular facet.

FIG. 3-A

Roentgenogram made April 21, 1952, showing range of motion.

The femur appeared displaced posteriorly about three to four centimeters. It could not be brought forward on the tibia. Posteriorly, subperiosteal dissection of the tissues about the distal end of the femur was carried out, freeing that portion of the bone. Reduction was then accomplished. The patella was resected and the wound was closed. With the knee in flexion of 45 degrees, a plaster-of-Paris cast was applied from the proximal portion of the thigh to the toes. The patient was returned to her bed in good condition.

On September 6, 1951, check-up roentgenograms revealed that the dislocation had recurred. On September 10, 1951, the patient was given a general anaesthetic of pentothal, the cast was removed, and Kirschner wires were inserted through the lower end of the femur and the upper end of the tibia. Traction in an anterior direction at right angles was applied to the Kirschner wire in the femur and traction distally over the foot of the bed was applied through the tibial wire. The limb was carried in a Thomas splint with Hodgson attachment, suspended on an overhead frame.

Roentgenograms made on September 15, 1951, showed good reduction. On September 21, 1951, a snug plaster-of-Paris cast was applied, incorporating the Kirschner wire pins and spreader in the cast in flexion of 45 degrees at the knee (Fig. 2). The patient was allowed to go home on September 22, 1951.

FIG. 3-B

April 21, 1952.

On October 22, 1951, she returned to the office and the cast was removed. Roentgenograms showed satisfactory reduction. The right quadriceps muscle was quite weak. All protection was removed and the patient was given instructions in quadriceps-strengthening exercises and was instructed to become ambulatory with crutches.

She was seen again on November 12, 1951. She was gaining good function of the knee, with about 20 degrees of motion, and was ambulatory on crutches with limited weight-bearing. The roentgenograms were satisfactory.

The patient was last seen on April 21, 1952, at which time she had flexion of 100 degrees and was walking without crutches (Figs. 3-A and 3-B). The left leg showed solid union as well.

AN EXPERIMENTAL ATTEMPT TO STIMULATE LINEAR GROWTH OF LONG BONES IN RABBITS

BY CHARLES H. HERNDON, M.D., AND GEORGE E. SPENCER, M.D., CLEVELAND, OHIO

From University Hospitals of Cleveland

Present-day techniques employed to equalize limb-length discrepancy are not entirely satisfactory. The hazards of limb-lengthening procedures have largely limited the possible approaches to methods of shortening or retarding the growth of an extremity which is commonly normal in length. If one could develop a technique that would permit controlled stimulation of growth of the short extremity, a more satisfactory result might be anticipated.

It is well known that osteomyelitis, tumors, fractures, and certain surgical procedures adjacent to an epiphyseal plate may produce local overgrowth of the involved long bone. This knowledge has led many orthopaedists to try to stimulate linear growth through a variety of surgical procedures. Multiple drilling of the metaphysis, subperiosteal stripping, and recently, the introduction of screws adjacent to the epiphyseal plate have been tried with a varying degree of success. A recent review of the literature relative to this problem is available[4].

In an attempt to develop a technique for the local stimulation of linear growth, the authors reviewed the literature dealing with the effect of various metals on bone[1,2,3,6]. It would appear from the work of Zierold and others that copper will produce a definite irritating effect when introduced into bone but not actual destruction. We, therefore, arbitrarily selected soft electrolytic copper wire (12B and S gauge)* as metaphyseal implants in an attempt to stimulate epiphyseal growth.

This work was carried out in 1948 and 1949, but was not reported because of reluctance to present a purely negative report. Recent interest in the subject, however, has prompted the authors to make known the results of these experiments.

FIG. 1-A

FIG. 1-B

Rabbit 535. Operation was on June 15, 1948. A soft electrolytic copper wire plug was driven into a drill hole 0.5 centimeter proximal to the distal femoral epiphysis.

Fig. 1-A: Roentgenogram made on July 13, 1948, four weeks after operation. The copper plug had grown away from the epiphyseal plate and was 1.1 centimeters from the epiphyseal line.

Fig. 1-B: Roentgenogram made August 12, 1948.

* Furnished by the Anaconda Copper Company.

FIG. 1-C

FIG. 1-D

Fig. 1-C: Roentgenogram made September 23, 1948.

Fig. 1-D: Roentgenogram made November 7, 1948. This animal was sacrificed on January 10, 1949, seven months after operation. The femora were removed and measured with calipers. The femur with the copper insert measured 11.1 centimeters and the opposite femur measured 11.1 centimeters.

Rabbits three to four weeks of age were operated upon under general anaesthesia. A drill hole was made immediately proximal to the lower femoral epiphysis and a plug of soft electrolytic copper was driven in. Growth of the extremities was followed by roentgenograms at monthly intervals. In an attempt to place the copper plug as close to the epiphyseal plate as possible, the plate was damaged in certain instances and epiphyseal fusions were produced. In these instances, the animals were removed from the study. Ten of the animals which grew to maturity were satisfactory for study.

At seven months of age, the animals were sacrificed and both femora were removed. The length of the femora was measured with calipers. Three of the femora containing copper were an average of 0.23 centimeter longer than the opposite femora, six containing copper plugs were an average of 0.23 centimeter shorter than the opposite femora, and the length of one containing copper was equal to that of the opposite femur. Roentgenograms made during the course of the experiment revealed that the copper plug grew away from the epiphyseal plate quite rapidly, averaging 0.5 centimeter during the first month.

We must conclude from these results that copper plugs implanted adjacent to the lower femoral epiphysis in rabbits will not appreciably influence linear growth. It is hoped that other materials will be tried and that eventually a substance may be found which will produce consistently controlled stimulation of linear growth. A recent preliminary report by Wilson in this regard is encouraging.

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NEEDLE BIOPSY OF THE LUMBAR VERTEBRAL BODIES

A Modification of the Valls Technique

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The value of needle biopsy as a technique for the clinical diagnosis of bone lesions has been well established[1,2,3,4,5,6,7,9]. The purpose of this paper is to describe a simple modification of the Valls technique of biopsy of the lumbar vertebral bodies which allows the accurate placement of the needle.

The equipment (Fig. 1) consists of a calibrated metal rod, fourteen centimeters long, fixed to a lucite base in which radiopaque markers are placed at half-centimeter intervals, a stainless-steel centimeter rule with a sliding pin which can be fixed with a set screw, a guide channel on one end of the rule placed at an angle of 55 degrees with the rule (as originally described by Valls), a 14-gauge needle, a trephine of the same diameter fitted with an obturator, and a thin stainless-steel sheath just large enough to accommodate the needle and trephine.

With the patient in a prone position on the x-ray table and the calibrated rod in place on the skin over the spinous processes, lateral and postero-anterior roentgenograms are taken of the lumbar spine. On the lateral film, the distance from the skin to the anterior

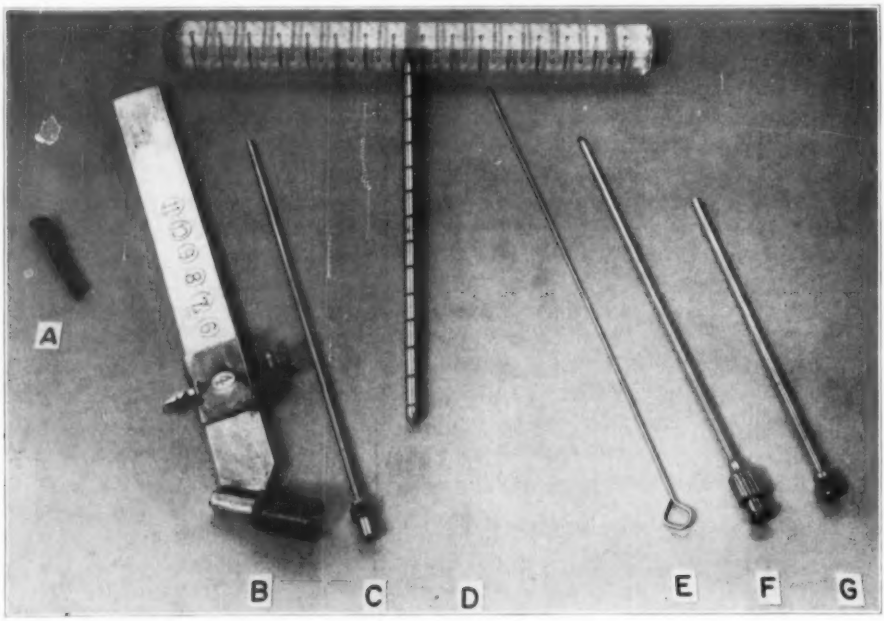

FIG. 1

Equipment for needle biopsy:
A. Rubber adapter for attaching syringe to biopsy needles;
B. Valls' needle guide;
C. No. 14 trephine with shank to fit hand drill;
D. Centimeter rule fixed to lucite base in which markers are incorporated at half-centimeter intervals;
E. Obturator for removing biopsy from trephine;
F. No. 14 hypodermic needle for infiltrating tissues with local anaesthetic;
G. Metal sheath for needle and trephine.

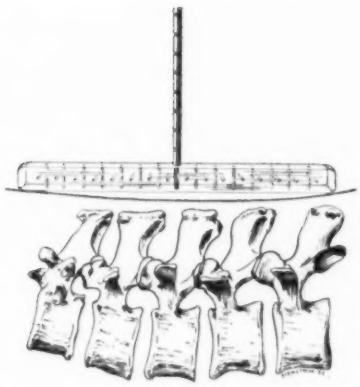

FIG. 2

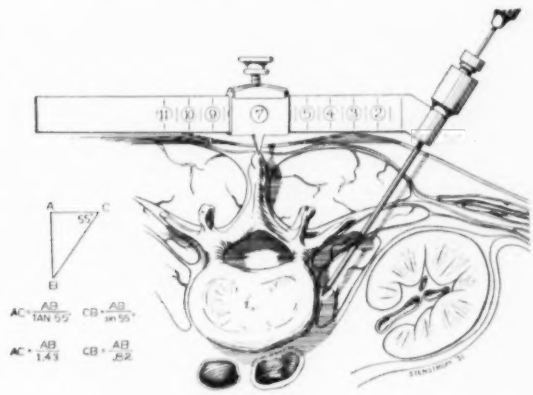

FIG. 3

Fig. 2: Diagrammatic representation of the lateral roentgenogram of the lumbar spine with the metal ruler in place.

Fig. 3: Diagrammatic representation of the method used for calculation of the distance from the mid-line to the point for insertion of the needle.

portion of the vertebral body is measured, the measuring rod being used to compensate for distortion (Fig. 2). From this measurement, by means of simple trigonometry, the distance the needle must be inserted from the mid-line in order to strike the vertebral body and yet to avoid the transverse process is calculated: the measured distance from skin to anterior surface of vertebral body divided by 1.43, the tangent of 55 degrees (Fig. 3). The distance from the point of insertion to the anterior portion of the body may also be calculated. On the postero-anterior roentgenogram, the spinous process at the level of the lesion is identified. The calibrated rod is then removed and the skin is prepared. Under sterile conditions, two skin wheals are made with local anaesthesia: one over the spinous process, and the second directly lateral to the spinous process at the distance from the mid-line previously calculated. The pin on the guide, which has previously been sterilized, is set at the calculated distance and is inserted through the skin and subcutaneous tissues to the spinous process. Under local anaesthesia, a small incision is made in the skin opposite the guide channel, and the skin edges are retracted while the needle and sheath are inserted through the channel. Care must be taken to hold the guide in a horizontal position. The needle and sheath are inserted until the bone is contacted, following which lateral and postero-anterior roentgenograms are again made to confirm the fact that the needle is in the desired position for biopsy. The needle can then be withdrawn, leaving the sheath in place, and the biopsy can be obtained by means of the trephine. The method has proved simple, accurate, and rapid. General anaesthesia can be avoided, and the danger of penetrating the aorta or vena cava with a large caliber needle is eliminated.

During the past four years, forty-eight needle biopsies of the lumbar vertebral bodies have been performed and positive diagnoses have been established in twenty cases: tuberculosis (diagnosed either by culture or histological section), six; metastatic carcinoma, four; Ewing's sarcoma, one; multiple myeloma, one; syphillis, one; non-specific inflammatory reaction, seven; negative biopsies (including osteoporosis in which biopsy was carried out to rule out neoplasm), twenty-eight.

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A SIMPLE AND EFFICIENT METHOD OF SECURING BIVALVED CASTS IN POSITION

BY PAUL V. HUTCHINSON, M.D., PITTSBURGH, PENNSYLVANIA

With the cooperation of The Sarah Mellon Scaife Foundation's Multiple Fellowship on Orthopaedic Appliances, Mellon Institute, Pittsburgh, Pennsylvania

A simple and efficient method of making bivalved casts is presented which has been of considerable help, both as a time saver and in the reduction of cost to the patient. When catches are incorporated in the cast (Figs. 1-A and 1-B) during its construction, a removable cast is completed as soon as the plaster is dry and the stockinette is secured (Figs. 1-C and 1-D). This eliminates the necessity of bivaling casts and sending them to the brace maker

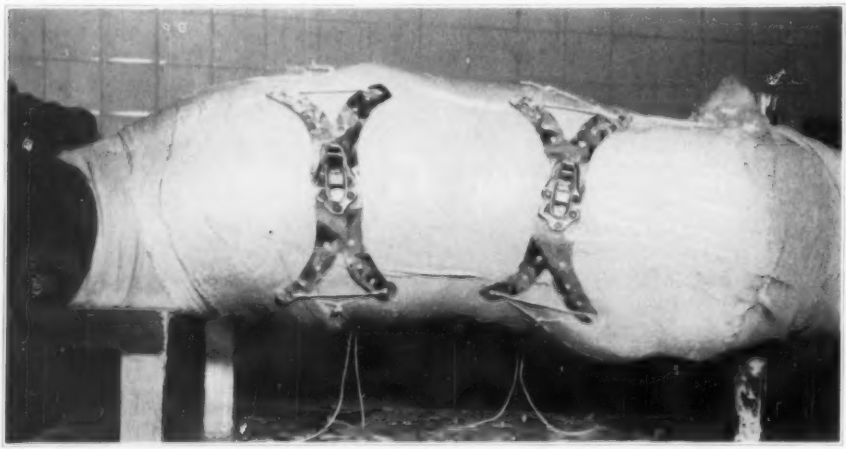

FIG. 1-A

Fig. 1-A: Cast is three quarters completed. The chest catches are tied to the cast.

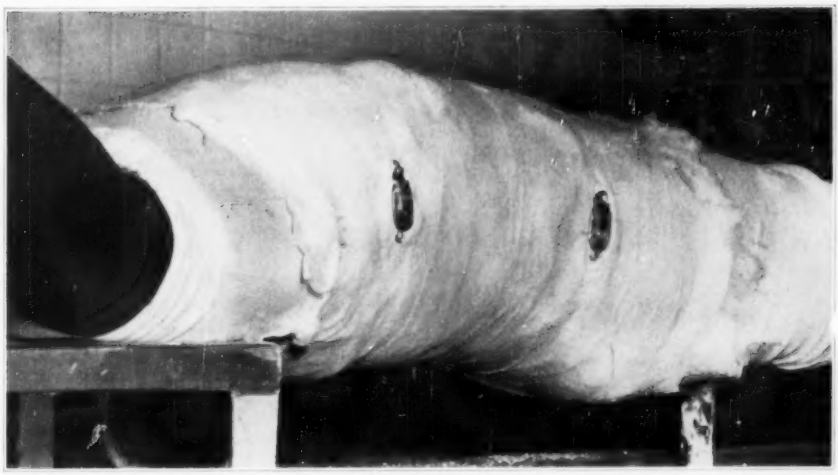

FIG. 1-B

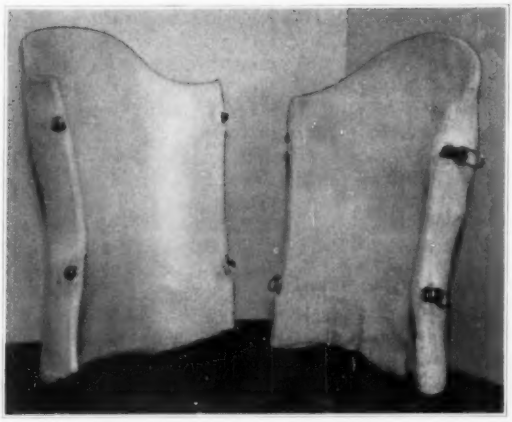

FIG. 1-C

FIG. 1-D

Fig. 1-B: Photograph shows finished cast and trimming. It is now ready for bivalving.

Figs. 1-C and 1-D: Photographs show finished cast and the chest-catch assembly.

Fig. 2: Grid-line photograph of the chest cast catch.

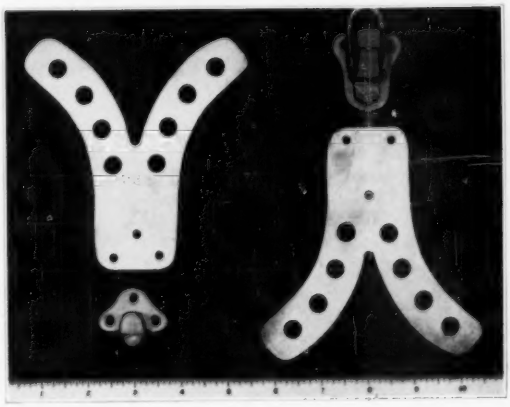

FIG. 2

for the application of straps and buckles or whatever method is used locally for securing a bivalved cast. The assembly as shown in the photographs consists of chest catches, riveted to anchors, the anchors being made of a thin-gauge aluminum or other metal which will conform to the contour of the cast (Fig. 2). These casts have been used on husky coal miners for as long as four months. The assembly has held up satisfactorily.

LOWER NEPHRON SYNDROME FOLLOWING PROLONGED KNEE-CHEST POSITION

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The clinical picture of lower nephron syndrome has been observed and described since World War I [16, 20, 22, 26, 27, 30]. Little interest in the condition was shown, however, until Bywaters and his associates studied the results of crushing injuries during the bombing of London in World War II [3, 4].

The syndrome has been associated with numerous types of injuries and intoxications, the more common being crushing injuries [9, 11, 23], transfusion reactions [1, 6, 8], burns [14, 19], heat stroke [18, 24], various types of intoxication [7, 12, 13, 15, 29, 31], toxaemias of pregnancy [33], blackwater fever [32], and diverse other conditions [5, 17, 21, 25, 34].

The lower nephron syndrome following muscle-crushing injuries has been especially frequent during war time. Varying types of muscle injuries producing the syndrome have also been seen in peace-time practice. It is the purpose of this paper to present a case of lower nephron syndrome which followed muscle injury resulting from an unusual operative position in which pressure was maintained on the lower extremities for a prolonged period of time.

REPORT OF A CASE

A white male, thirty-five years old, was admitted to the Hospital complaining of aching in the lower mid-back for four years, and of numbness in the anterior lateral aspect of the right thigh for two and one-half months.

He had been discharged from the Army in December 1943 because of back pain. He had then been symptom-free for two months, but thereafter had had recurring aching in the lower back, which had recently been associated with numbness of the lower third of the anterolateral aspect of the right thigh. There was no radiation of pain into either lower extremity, and he did not limp. There had been a severe exacerbation of the pain in the lower back three days before admission, with difficulty in walking.

Physical Examination

The patient was an obese white male seventy-five inches tall, weighing 240 pounds, whose physique was female in type, with female distribution of hair. He was severely incapacitated by pain in the lower mid-back. The blood pressure was 104 systolic, 78 diastolic, the radial pulse was 76 per minute, and his temperature was normal. Examination of the heart was negative. Neurological examination disclosed findings compatible with a diagnosis of herniated nucleus pulposus at the level of the fourth and fifth lumbar vertebrae on the right. This was confirmed by a myelographic study.

Preoperative Laboratory Findings

Bleeding time	2 minutes
Coagulation time	6 minutes
Red blood cells	5,000,000 per cubic millimeter
Hemoglobin	16.5 grams
White blood cells	9,100 per cubic millimeter
The differential count was normal.	
Blood glucose	113 milligrams per 100 cubic centimeters
Spinal fluid:	
Total protein	18 milligrams per 100 cubic centimeters
Sugar	69 milligrams per 100 cubic centimeters

The spinal-fluid Wassermann reaction was negative and the gold curve was flat. The basal metabolic rate was plus 15. Urinalysis showed a specific gravity of 1.012, with negative reactions for albumin and sugar. A Kahn test on serum was negative.

Operation

A hemilaminectomy on the right at the level of the fifth lumbar vertebra was performed under endotracheal anaesthesia. Because of the patient's obesity and height, he was placed in the knee-chest position,

so that maximum widening of the intervertebral spaces could be obtained (Fig. 1). The exploration failed to reveal a disc herniation; further exploration was discontinued because of the marked cyanosis and swelling which developed in the lower extremities as a result of the unusual position in which the patient had remained for approximately three hours.

Throughout the operation the blood pressure was maintained at approximately 110 systolic, 70 diastolic. The radial pulse varied from 70 to 80 per minute and the respirations varied from 22 to 30 per minute.

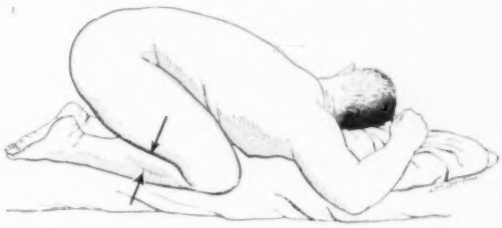

FIG. 1

Operative position used to obtain maximum widening of intervertebral spaces. Note the resulting compression of the calf muscles.

Hospital Course

Within the next few days the swelling of the lower extremities subsided appreciably. The patient complained only of pain at the operative site. There was also persistent vomiting, as well as some difficulty in urination. Catheterization, followed by tidal drainage, was instituted. For the first three days after operation, there was adequate intake and output of fluids. On the fourth day, only thirty-five cubic centimeters of urine was voided. The next day there was relative anuria and the patient complained of pain deep in the abdomen in the right lower quadrant.

Further examination disclosed signs pointing to phlebothrombosis of the lower extremities, although hemoglobinuric nephrosis was mentioned as a possibility. The alarming persistence of renal suppression with resultant azotaemia prompted an exploration of the femoral veins on the assumption that there might have been an extension of thrombosis up the vena cava, involving the renal veins bilaterally. No phlebothrombosis was found. During this period, the blood urea nitrogen rose to 132 milligrams per 100 cubic centimeters and the blood creatinine rose to 14 milligrams per 100 cubic centimeters. The urine showed an acid reaction, + + albumin, numerous white blood cells, and a moderate number of red blood cells.

Despite all therapeutic efforts, the azotaemia increased and the patient died seven days after the initial operation. During the entire operative and postoperative period, the patient had received a total of 1,500 cubic centimeters of blood, 500 cubic centimeters at each operation and 500 cubic centimeters on the ward.

POSTMORTEM EXAMINATION

Gross Findings

The body was that of a well developed, markedly obese white male. The lower extremities were oedematous up to the knees.

The heart weighed 475 grams. The epicardium was smooth, with a large amount of subepicardial fat. The myocardium, valves, endocardium, and coronary arteries were normal. The aorta showed moderate atheromatous changes in the abdominal portion. The renal arteries were unaltered.

Each kidney weighed 340 grams. The capsule of each kidney was tense and stripped easily, leaving a smooth, pale brown cortical surface. On section, the cut surfaces bulged slightly. They were pale, light brown, with ill-defined red striations, especially at the corticomedullary junction.

The superior and inferior venae cavae, the renal veins, and the iliac veins were free of thrombi. Both femoral veins were found ligated and sectioned. The distal portions of the ligated veins were occluded by recent thrombi.

The lungs were oedematous. The liver was congested.

The muscles of the calves of the legs were markedly oedematous. Pin-point hemorrhages were noted in the deeper portions of the right and left gastrocnemius muscles.

A herniated nucleus pulposus was present between the fourth and fifth lumbar vertebrae at the midline. The herniation measured 3.5 by 2 centimeters. The mass was resilient and rubbery. No compression of the spinal cord was noted.

Microscopic Findings

The pertinent microscopic changes were noted in the kidneys and in the calf muscles. Sections of kidney (Fig. 2) showed slight amounts of albuminous fluid in the glomerular spaces. The glomerular tufts were unaltered. The proximal portions of the nephrons showed minimal changes. The brush borders of the cells of the proximal convoluted tubules were indistinct, and an occasional proximal tubule contained an eosinophilic protein cast. The distal portion of the nephron, on the other hand, revealed extensive damage. The distal convoluted tubules were necrotic. The surrounding interstitial tissue was infiltrated with neutrophils, a few histiocytes, and occasional eosinophils. Heme casts in the lumina of the distal convoluted tubules were a conspicuous feature. In most instances these casts were intermixed with inflammatory cells and cellular debris. Some of the small veins adjacent to the damaged tubules showed thrombophlebitis.

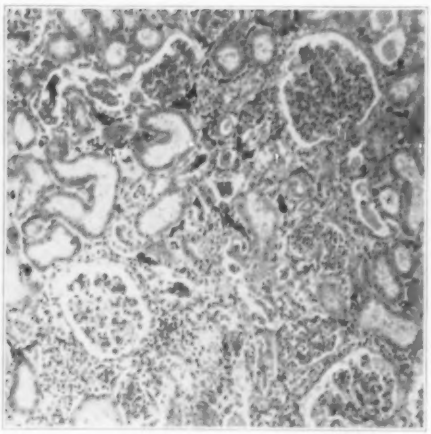

FIG. 2

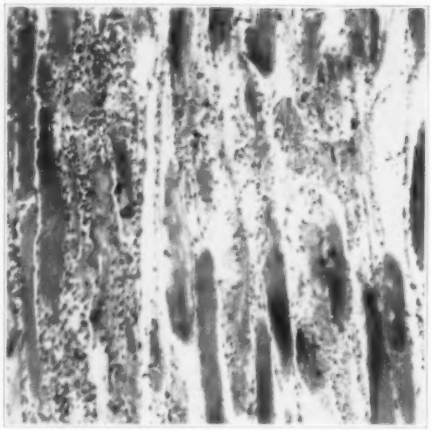

FIG. 3

Fig. 2: Photomicrograph (× 85) of section from kidney showing necrosis of the distal portions of the nephrons with heme and purulent casts. (Hematoxylin and eosin stain.)

Fig. 3: Photomicrograph (× 85) of section from calf muscle, showing degeneration of sarcolemma and interstitial inflammatory changes. (Hematoxylin and eosin stain.)

Sections from the calf muscles (Fig. 3) showed swelling of the muscle fibers, many of which were necrotic. Some fibers demonstrated only loss of transverse striations. Others revealed a homogeneous hyalinization of the sarcoplasm. Many muscle fibers were completely disorganized, and only the sarcolemma remained, which enclosed vacuolated fragments of degenerated sarcoplasm and a few muscle nuclei. Where the muscle fibers were fragmented, there was proliferation of muscle nuclei intermixed with inflammatory cells of both the mononuclear and polymorphonuclear varieties. There were also histiocytic cells containing phagocytized debris and a light brown pigment, probably lipochrome. There was considerable interstitial oedema and frank extravasation of blood.

DISCUSSION

There are three possible bases for the development of a lower nephron syndrome in this case: transfusion reaction, vomiting, and muscle necrosis.

Transfusion

The patient had received a total of 1,500 cubic centimeters of blood, 500 cubic centimeters at each operation and 500 cubic centimeters on the ward postoperatively. It is to be noted that only one transfusion of 500 cubic centimeters of blood had been given prior to the onset of anuretic symptoms. However, there had been no clinical or laboratory evidence of any reaction to this or subsequent transfusions. Although one cannot totally exclude this possibility, the likelihood of the transfusion having precipitated the lower nephron syndrome is quite remote.

Vomiting

There had been persistent vomiting immediately following operation. Although severe vomiting has been shown to produce the renal lesions of the lower nephron syndrome [25], vomiting is more frequently part of the clinical manifestation of the syndrome, because of its intimate relationship to dehydration, malnutrition, and disturbances in electrolyte balance. Vomiting tends to aggravate the oliguretic state [2]. In patients with lower nephron syndrome, the absence of vomiting is apparently related to the mildness of the clinical state.

Muscle Necrosis

Muscle necrosis appears to be the most probable precipitating factor in the development of a lower nephron syndrome in this case. There was ample evidence of muscle dam-

age. Immediately following surgery, the lower extremities had been cyanotic and oedematous. In addition, there had been further compression of the lower extremities with elastic bandages. Finally, there was the inescapable postmortem evidence of severe damage to the calf muscles.

The mechanism of development of the lower nephron syndrome as the result of muscle damage is not clear. It is presumed that myohemoglobin released from damaged muscle has a low renal threshold. Myohemoglobin has a molecular weight of 17,500, in contrast to hemoglobin, which has a molecular weight of 68,000. The relatively small size of the myohemoglobin molecule would appear to permit its passage through the unaltered glomerular membrane. Myohemoglobin is released rapidly from damaged muscle and thus contributes to the rapid overloading of the kidneys.

It has never been clearly shown that myohemoglobin in itself is toxic. Some investigators have claimed that there are degradation products of myohemoglobin which are toxic, especially in an acid medium. It has also been suggested that it is the mechanical blocking of the tubules by these degradation pigments which produces the renal damage. Oliver's dissections have failed to reveal complete obstruction. In addition, contrary to what one would expect if the damage were due to mechanical obstruction, the proximal portions of the nephrons rarely show dilatation. Finally, no convincing evidence has been presented that degradation products which cause renal damage are released in ischaemic muscles.

In this case, it appears most probable that the muscle damage from an unusual operative position was the basis for the development of the lower nephron nephrosis. Davidoff has used this position in about sixty disc operations in patients of all sizes without incident. He has said that: "It is possible for such complications to result from this position if the weight of the patient's body rests entirely on the calves. We are very careful to have a projection up from the table so that the patient's buttocks rest on a sort of seat arrangement and the weight of the body does not fall on the above place."

Figure 1 demonstrates how compression of the calf muscles in the classical knee-chest position, particularly in an obese individual, can result in ischaemic necrosis.

NOTE: The photomicrographs and drawing were made by the Medical Illustration Service, Mr. Sidney Shapiro, Chief.

The authors express their appreciation to the Neurosurgical Service for the elucidation and description of the surgical problems and procedures in this case.

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SCOLIOSIS WITH PARAPLEGIA

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From the Lakeville State Sanatorium, Middleboro *

Forty-seven cases of scoliosis associated with paraplegia [2] have now been reported in the literature, indicating the extreme rarity of the condition as compared with the total number of cases of scoliosis seen throughout the world.

The most recent and complete review of the condition was given by McKenzie and Dewar, who emphasized the value of timely laminectomy with division of the dura. They believed that spine fusion was neither desirable at the time of laminectomy, nor necessary at a later date.

In the majority of cases recently reported (thirty-seven out of forty-six in Kleinberg and Kaplan's series, and thirty-two out of forty-six in McKenzie and Dewar's) the paraplegia was found to occur at the period of most rapid growth, between the ages of eleven and nineteen years. Although scoliosis is seen most commonly in girls, it has been noted by various observers that the occurrence of paraplegia as a complication is seen most often in males [2].

In the case to be reported the deformity was due to von Recklinghausen's disease. It is of special interest since complete recovery from paraplegia was achieved as a result of spine fusion alone. Previous to this, to the author's knowledge, spine fusion as the only operative treatment has been reported once [4]. In that case there was, however, no improvement in the degree of paralysis, although the fusion was regarded as sound. There are records of two cases of paraplegia developing in patients suffering from von Recklinghausen's disease. In one of these [4] the course and outcome are not known. In the second [1], laminectomy and division of the dura were performed, but no improvement was observed in the year following operation.

CASE REPORT

D.M.S., a white girl, was born in 1933 of Portuguese parents. When she was nine years old her parents noticed that her back was "crooked", and she was observed in a children's hospital. She was untreated until the age of twelve, when she was seen at a general hospital where her physical examination revealed a right thoracic and left lumbar scoliosis in which fair passive correction was possible. No disturbance of the extremities was noted. Attempts to control or correct the curve were unsuccessful because of lack of cooperation by the child's parents.

The child had no pain and was able to walk and play normally until August 1948 when, at the age of fifteen years, she suddenly fell while playing croquet. She had difficulty in moving her lower extremities and immediately noticed numbness and tingling in them. The weakness and numbness of the lower limbs became gradually more severe and in January 1949 she was admitted to a children's hospital. There she was found to have a severe high thoracic scoliosis with a spastic paraplegia, together with sensory loss below the level of the tenth thoracic vertebra. Voluntary movement in the lower limbs was limited to very slight flexion and internal rotation of the left hip. *Café au lait* spots were widely distributed over the body and extremities.

A myelogram carried to the level of the ninth thoracic vertebra failed to demonstrate a definite block. The patient was placed in plaster shells in slight hyperextension. This was rapidly followed by improvement in voluntary power, in that the child could flex and abduct the hips and extend the knees. The sensory level, however, remained unchanged.

The patient was transferred to Lakeville State Sanatorium in February 1949. Examination on admission revealed a severe thoracic kyphoscoliosis and an incomplete paraplegia with sensory loss at the level of the tenth thoracic vertebra. Muscle examination revealed spastic paralysis of both lower limbs, with a trace of voluntary power in the abductors and flexors of the hips and poor power in the quadriceps. Hypo-aesthesia was present distal to the level of the umbilicus and anaesthesia was present in the right calf. There was no interference with micturition or bowel control. There was increase in both knee and ankle jerks bilaterally. Ankle clonus was present bilaterally, as were bilateral Babinski reflexes.

* Service of Paul Norton, M.D.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Anteroposterior roentgenogram made at admission, February 17, 1949. Right curve, from the fourth thoracic vertebra to the eleventh thoracic vertebra, with the apex at the eighth thoracic vertebra, measured 110 degrees.

Fig. 1-B: Lateral roentgenogram made at admission.

FIG. 2-A

FIG. 2-B

Fig. 2-A: Roentgenographic appearance two years after operation, November 14, 1951. The curve at this time measured 91 degrees.
Fig. 2-B: Lateral roentgenogram two years after operation.

Roentgenographic examination revealed a right thoracic curve, measuring 110 degrees and extending from the fourth thoracic vertebra to the eleventh thoracic vertebra, with the apex of the curve at the eighth thoracic vertebra. The posterior aspects of the vertebral bodies at the apex of the curve were cavitated (Figs. 1-A and 1-B). Conservative treatment, with traction, plaster beds, and a Bradford frame, was tried for three months without any appreciable alteration in the motor paralysis or in the level or severity of the sensory loss. Laminectomy was therefore considered advisable, to relieve the cord pressure. It was felt that, in order to ensure stability and prevent further increase in the curve, a preliminary fusion should be done. It was planned to fuse the concavity of the thoracic curve, with a massive bone graft placed between the end points of the curve.

Operation was undertaken on June 7, 1949, when the patient was sixteen years of age, but was not carried out according to the preconceived plan, as the patient's condition during the procedure necessitated a rapid and less extensive dissection. After minimal soft-tissue dissection, decortication of the spinous processes, laminae, and transverse processes on the left side was carried out. A shaped full-thickness graft was placed in the concavity of the major curve in as straight a line as possible, some difficulty being encountered in fitting the graft to the extreme anteroposterior component of the curve. No attempt was made to correct the curve during the operative or postoperative period.

FIG. 3

Photograph of patient on November 14, 1951, two years after operation.

Eight days after operation it was found that a remarkable degree of neurological improvement had occurred. Sensation was good in the previously hypo-aesthetic area and voluntary power had returned in all the muscle groups of both lower limbs. The neurological improvement continued during the postoperative period and within four months of operation the sensations in the lower limbs could be regarded as normal. Within six months muscle power in all groups in both lower extremities was considered to be within normal limits. In January 1950, six months after operation, it was believed that the roentgenographic appearance of the grafted area indicated a pseudarthrosis at the superior end. However, exploration revealed the graft to be well incorporated in the spine at both superior and inferior ends. The patient was up and active in a "celastic" jacket from February 1950. She had no paraesthesia or numbness and no muscle weakness. She was discharged on April 26, 1950.

She was readmitted on November 13, 1951, at the age of eighteen, for removal of two small neurofibromata. She was walking well, had no weakness of the lower limbs, and sensations were normal. Roentgenographic examination at this date, two and a half years following spine fusion, showed that the curve now measured 91 degrees and that fusion was solid (Figs. 2-A and 2-B). There had therefore been a decrease of 19 degrees in the major curve, which had measured 110 degrees preoperatively.

COMMENT

It is difficult to explain the rapid and complete recovery of the paraplegia following spine fusion. It is possible that the dissection in the concavity of the curve, although minimal, effected sufficient loosening of taut structures to allow slight correction of the curve. The 19 degrees of correction, which was apparent from comparison of the preoperative and postoperative roentgenograms, was presumably sufficient to remove the pressure of the dura on the convex aspect of the cord. The myelogram was carried to the level of the ninth thoracic vertebra, but did not reach to the apex of the curve at the eighth thoracic vertebra, which corresponded with the level of cord pressure. The presence of a block cannot therefore be disproved.

It has been shown by McKenzie and Dewar that, in idiopathic scoliosis with paraplegia, laminectomy and decompression of the cord will suffice. However, in scoliosis associated with such conditions as osteogenesis imperfecta or neurofibromatosis affecting bone, it is felt that fusion is imperative if the progress of the scoliosis is to be checked and further cord pressure prevented.

In these and similar conditions, if the associated paraplegia is incomplete and of only short duration, it is suggested that a preliminary fusion in the concavity of the curve may safely be embarked upon. Should no recovery occur in the paraplegia, decompression of the cord may then be performed with the comforting knowledge that no increase in the degree of curvature is to be anticipated.

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A NEW CLAMP FOR USE IN FRACTURE SURGERY

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There has already been published in this *Journal*[1] an article presenting a type of bone forceps which can be easily handled with one hand and which serves to coapt bone fragments and also to fix a plate temporarily, before it is screwed to the bone. We have made a slight modification in this instrument which is of such importance and makes the instrument of so much greater value that we believed it also should be called to the attention of *Journal* readers.

Fig. 1

The lower jaw of the forceps is now made with a sharp and more or less pointed end, so that it can be easily inserted under the bone and through the periosteum. There is no need to free the bone from its surrounding tissues. The upper jaw is wide, as in the previous design.

The main indications for the use of such a forceps is in bone-grafting, either inlay or onlay graft, the lower jaw finding its support on the bone and the upper jaw serving to hold and also to press and even to crush the bone grafts before definite fixation is applied.

1. Verbrugge, Jean: An Improved Bone Clamp and a Plate for Internal Fixation of Fractures. J. Bone and Joint Surg., **28:** 174–175, Jan. 1946.

REPORT OF THE COMMITTEE TO STUDY THE PRESERVATION OF BONE *

During the year 1951 your Committee to Study the Preservation of Bone sent questionnaires to the membership of the Academy. This was done in an attempt to accumulate significant data on a large number of cases in which bank bone had been used. Of the 1,217 questionnaires sent out 577 were returned. Two hundred of the questionnaires were from orthopaedic surgeons who had had experience with the bone bank. The results of this study were based on an analysis of these 200 returns and especially on the 120 returns which listed the individual types of cases in which the bank bone had been used. Thus the complications encountered, together with the results, were analyzed in more than 3,000 cases in which bank bone had been used.

TABLE I

SUMMARY OF QUESTIONNAIRES RETURNED

	No.	Per cent.
Total no. of questionnaires returned	577	
No. not using bank bone	377	65.3
No. using bank bone	200	34.7
No. giving total number of cases	144	25.0
No. listing individual types of cases	120	20.8

The results of this analysis are summarized in Tables I to VI.

TABLE II

TYPE OF CONTAINER USED, CULTURE OF BONE, AND METHOD OF PRESERVATION AS LISTED IN 200 QUESTIONNAIRES RETURNED

	No.	Per cent.
Type of container used		
Single bottle	86	43.0
Double bottle	90	45.0
Other	24	12.0
Total	200	
Culture of Bone		
Culture	143	71.5
Culture not made	57	28.5
Total	200	
Method of preservation of bone		
Frozen bone	146	73.0
Merthiolate solution	32	16.0
Combination	16	8.0
Zephiran chloride	6	3.0
Total	200	

In 630 of the total of 3,104 cases, merthiolate-preserved bone was used. Of the total of eighty-seven reported cases of infections, thirty were in cases in which merthiolate-preserved bone was employed. Thus an incidence of infection of 4.8 per cent. was noted in cases in which merthiolate-preserved bone was used against an incidence of 2.3 per cent. in the remaining 2,474 cases, in the vast majority of which frozen bone was used.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 28, 1953.

TABLE III

NUMBER OF CASES PER QUESTIONNAIRE
(Total of 4,648 Cases Reported in 144 Questionnaires Returned)

No. of Cases	No. of Questionnaires	Per cent.
< 10	63	43 7
10 to 19	17	11 8
20 to 29	10	6 9
30 to 39	12	8 3
40 to 49	7	4 9
50 to 59	9	6 2
60 to 69	4	2 8
70 to 79	5	3 5
80 to 89	6	4 2
90 to 99	2	1 4
100 to 199	7	4 9
200 and over	2	1 4
Total	144	100 0

TABLE IV

TYPES OF CASES AS LISTED IN 120 QUESTIONNAIRES RETURNED

Type of Case	No.	Per cent.
Major non-union	494	15 9
Minor non-union	85	2 7
Spine fusion	1,464	47 2
Obliteration defects	371	12 0
Known infectious defects	52 *	1 7 *
Fresh fracture	300	9 7
Arthrodesis	315	10 1
Other	75	2 4
Total	3,104	100 0

* Included in number of obliteration defects.

The incidence of aseptic absorption was about the same regardless of the method of preservation of the bone transplant.

The incidence of infection was 4 per cent. in 997 cases in which the bone transplant had not been cultured, as compared with an incidence of 2.2 per cent. in 2,107 cases in which the transplant was cultured for the presence of micro-organisms.

TABLE V

INFECTION AND ASEPTIC ABSORPTION AS LISTED IN 120 QUESTIONNAIRES RETURNED

Type of Case	Total No. of Cases	Infection		Aseptic Absorption	
		No.	Per cent.	No.	Per cent.
Major non-union	494	13	2 8	28	5 7
Minor non-union	85	2	2 2	6	7 1
Spine fusion	1,464	30	2 0	28	1 9
Obliteration defects	371	19	5 1	25	6 7
Known infectious defects	52 *	12 *	23 1 *	0	
Fresh fracture	300	13	4 3	10	3 3
Arthrodesis	315	10	3 2	11	3 5
Other	75	0		4	5 3
Total	3,104	87	2 8	112	3 6

* Included in number of obliteration defects.

TABLE VI

RESULTS AS LISTED IN 120 QUESTIONNAIRES RETURNED

Type of Case	Total No. of Cases	Type of Result: Good No.	Good Per cent.	Fair No.	Fair Per cent.	Failure No.	Failure Per cent.	Not Determined No.	Not Determined Per cent.
Major non-union	494	349	70.6	26	5.3	71	14.4	48	9.7
Minor non-union	85	62	72.9	8	9.4	13	15.3	2	2.4
Spine fusion	1,464	1,002	68.5	43	2.9	103	7.0	316	21.6
Obliteration defects	371	282	76.0	18	4.8	47	12.7	24	6.5
Known infectious defects	52 *	34 *	65.5 *	2 *	3.8 *	14 *	26.9 *	2 *	3.8 *
Fresh fracture	300	263	87.6	2	0.7	20	6.7	15	5.0
Arthrodesis	315	258	81.9	1	0.3	39	12.4	17	5.4
Other	75	63	84.0	0		7	9.3	5	6.7
Total	3,104	2,279	73.4	98	3.2	300	9.7	427	13.7

* Included in number of obliteration defects.

It is the opinion of your Committee that in an evaluation of bone transplants there is really no such thing as a fair result; the transplant is either a success or a failure. In the evaluation of the results of spine fusions some surgeons reported as "fair" those fusions in which there was solid union of the transplant across one interspace and pseudarthrosis at another; for the purposes of this analysis we feel these cases should be classified as failures. The same statement holds true for the group of major non-unions. It would also seem that many of the cases in the indeterminate classification must be failures. We feel that the "failure" incidence of only 7 per cent. and 14.4 per cent. respectively in the cases of spine fusion and major non-union is low, but there is no doubt of the figures. On the other hand, a percentage rate of 68.5 per cent. of good results in spine fusions is in accordance with similar results reported by most authors who have critically analyzed their cases.

Many of the preserved homogenous bone grafts were used to augment autogenous transplants. Many others were used in cases, such as fresh fractures and arthrodeses, in which there would have been union regardless of whether a transplant was used or not.

Of the total of 300 failures (Table VI), eighty-one were in cases in which merthiolate-preserved bone was used. The incidence of failure was 12.9 per cent. in the cases in which merthiolate-preserved bone was used and 8.9 per cent. in the remaining cases.

It is lamentable that we do not have a like series of autogenous transplantations the results of which could be compared with those just presented. We believe that the results in such a series would be consistently better. It has been shown experimentally and in individual smaller series that bank bone cannot replace autogenous bone. However, in certain well-selected cases we believe bank bone has its place. From our analysis complications are likely to be less and the chance of success greater if frozen bank bone is used in place of merthiolate-preserved bone. Every precaution, including culture of the bone stored in the bank, seems desirable in an attempt to decrease the incidence of infection. At present we have no suggestions which might help prevent aseptic absorption of homogenous bone transplants.

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FRED C. REYNOLDS, M.D.
PAUL R. LIPSCOMB, M.D., *Chairman*

BLASTOMYCOSIS OF BONE

Report of a Case

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North American blastomycosis (Gilchrist's disease) is an uncommon fungous disease occurring rarely in New England, its geographic distribution being chiefly in the mid-western and southern portions of the United States. Treatment of systemic blastomycosis is usually palliative at best and, according to most studies, the over-all mortality, when the skeletal system is involved, is about 89 per cent. In 1944 Colonna and Gucker found sixty-seven previously reported cases involving bone and reported a case with death. Alfred and Harbin in 1950 added another case involving bone which had failed to respond to therapy at the time of the report.

Case reports of this disease are infrequent. The case herein reported is of especial interest since the patient had spent his entire life in New England, and he has had apparently complete recovery from the disease. Only one other case of systemic blastomycosis has been reported in the State of Maine, the native state of this patient.

The following is a case of systemic blastomycosis involving bone and by history probably arising in the respiratory tract; the patient was treated with large doses of potassium iodide with apparently complete recovery.

Fig. 1

Roentgenogram of the right foot and ankle made at admission, February 16, 1951, showing the punched-out area of bone destruction in the calcaneus.

FIG. 2

February 16, 1951. Showing lesion of the medial condyle of the left femur.

CASE REPORT

A white male farmer, fifty-seven years old, was well until January 1950 when pneumonia and a pleural effusion developed. He was treated with penicillin and aureomycin, and several thoracenteses were done. During hospitalization an infection of the fifth finger of the left hand developed; this was incised and drained. Drainage continued and roentgenograms of the hand showed osteomyelitis of the proximal phalanx. When the infection did not subside, an amputation was done. The finger was examined in another laboratory and the lesion was reported as a chronic inflammation.

About one month later a draining sinus developed from the region of the right Achilles tendon. This was treated by incision and drainage. Sinuses of the amputation site of the left hand and of the right foot continued to drain. He was treated with penicillin, aureomycin, and chloromycetin for one month, during which time he had a low-grade fever. Two months before admission to the Maine General Hospital a draining sinus developed in the distal end of the left thigh and, one month before admission, another draining sinus in the distal end of the right thigh in the supracondylar area. The patient had been bedridden for five months before admission, and had lost twenty pounds in weight during the year before his admission.

Physical examination on admission revealed a thin, chronically ill male. The temperature was 98.8, the pulse 90, and the blood pressure 106 systolic and 70 diastolic. The chest was clear to percussion and auscultation. The following draining sinuses were noted: on the medial aspect of the lower portion of the right thigh, on the medial aspect of the left supracondylar area, on the lateral aspect of the right foot, and at the amputation site of the fifth finger of the left hand. Along the medial aspect of the right Achilles tendon was a poorly healed scar. There was limitation of motion of the left knee and of the right ankle. A roentgenogram of the chest revealed fibrosis at the left base suggestive of old infection without evidence of active pulmonary disease. Roentgenograms of the left hand, right foot and ankle, and of both knees were made. The roentgenogram of the right foot (Fig. 1) showed a punched-out area of bone destruction in the calcaneus, and a roentgenogram of the left femur (Fig. 2) showed an area of bone destruction in the medial condyle.

Laboratory findings at admission were as follows:

Red blood cells	3,280,000 per cubic millimeter
Hemoglobin	57 per 100 cubic centimeters
White blood cells	9,200 per cubic millimeter
Neutrophils	82 per cent.
Lymphocytes	17 per cent.
Monocytes	1 per cent.
Sedimentation rate	30 millimeters per hour (Wintrobe method)
Hematocrit	30 grams per 100 cubic centimeters
Blood urea nitrogen	13 milligrams per 100 cubic centimeters
Fasting blood sugar	81 milligrams per 100 cubic centimeters

The Hinton test was negative.

Urine was negative except for 2 to 4 red blood cells per high-power field and 1 to 2 white blood cells per high-power field.

Biopsy of the sinus tract of the left supracondylar area was performed. Sections showed granulation tissue with necrosis and scattered multinucleated giant cells. A second biopsy specimen was taken from this area to include bone. Sections revealed "a chronic granulomatous process, in which there is necrosis, in places somewhat suggesting tubercles, but not entirely characteristic, even though there are giant cells. Scattered throughout the inflammatory tissue, however, there are many organisms that have a central nuclear zone, with a rather sharp doubly contoured border. No endospores found." Figure 3 is tissue taken from the medial condyle of the left femur stained with a periodic-acid-Schiff stain and showing Blastomycetes. A culture could not be made, since the biopsy specimen had been received in the laboratory fixed in formalin.

The patient was given penicillin after the second biopsy and, as soon as the diagnosis of blastomycosis had been established, therapy with potassium iodide was instituted. Twenty-one drops per day in three divided doses of a saturated solution were given, and the dose was increased daily, so that after two and one-half weeks the patient was receiving 279 drops per day. The patient also received 1,500 cubic centimeters of whole blood, vitamins, and a high-caloric diet. The wounds were cleansed locally with ether and the dressings were changed frequently. The patient's improvement was progressive, with diminution of drainage from the

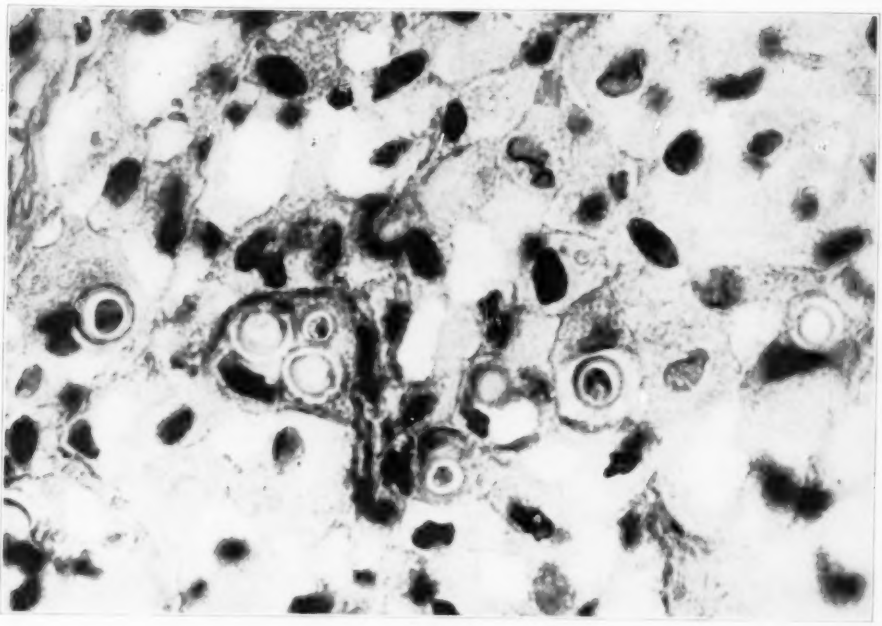

FIG. 3

Photomicrograph (× 1000) of a section taken from the medial condyle of the left femur, showing Blastomycetes in the process of budding.

FIG. 4

FIG. 5

Fig. 4: Roentgenogram made July 1952, one and one-half years after treatment, showing healing of the lesion of the medial condyle.

Fig. 5: Roentgenogram made in July 1952, revealed healing of bone destruction of the calcaneus of the right foot.

sinus tracts. At discharge, eleven and a half weeks after admission, drainage from the right knee and left hand had ceased and these wounds were healed. Drainage from the left knee and right foot was minimal. Roentgenograms made before discharge showed no appreciable change in the appearance of the bone lesions. On discharge the patient had gained weight, felt much improved, and was walking with crutches with considerable improvement in knee and ankle motion. He was discharged in May 1951, potassium iodide therapy being continued.

Laboratory findings at discharge were as follows:

Red blood cells	4,750,000 per cubic millimeter
Hemoglobin	92 per 100 cubic centimeters
Sedimentation rate	4 millimeters per hour (Wintrobe method)

When he was seen in the Out-Patient Department in July 1951, there was still slight drainage from the left knee and right foot. The patient was ambulatory without crutches; he was asymptomatic, and there were no signs or symptoms of iodism. Potassium iodide therapy was continued.

In December 1951 the patient appeared well with no complaints and the sinuses had been healed and dry for three months. The hemoglobin was 85 per 100 cubic centimeters. Potassium iodide therapy was continued at 180 drops daily for one week, alternated with a week without medication.

In July 1952 all sinuses were completely healed and dry and the patient was asymptomatic and was working full time in farming. He had gained weight and appeared entirely normal. Roentgenograms were made of the distal ends of both femora, both feet and ankles, both hands, the chest, ribs, thoracic spine, pelvis, and skull. There was no evidence of bone disease and the lesions previously present were found to be healing. Figures 4 and 5 show the roentgenograms of the left knee and right foot made at this time, about one and a half years after treatment, with healing of the lesions in the calcaneus and femur.

It was planned to continue potassium iodide therapy for one more year.

DISCUSSION

The source of infection in this disease is obscure, and transmission from animals has never been proved, although the condition is most prevalent among farmers and laborers. The portal of entry in this case, as in most cases of systemic blastomycosis, was apparently the respiratory tract and the first symptoms were referable to the lungs. Roentgenographically the appearance of the bone is not pathognomonic and is easily confused with that in tuberculosis, neoplasms, and especially coccidioidomycosis. The appearance is usually that of a well defined punched-out area with little surrounding bone reaction. All areas of the skeleton are susceptible to the disease; the ribs, vertebrae, skull, and tibiae are most often involved. Positive diagnosis probably depends on culture of the organism, but identification of the organism on permanent section obtained by biopsy is characteristic, and might be confused only with *Coccidioides immitis* and cryptococcosis or South American blastomycosis. In this case the diagnosis was established on permanent section of the biopsy. Sections show Blastomycetes in the process of budding as demonstrated in Figure 3, which differentiates this disease from coccidioidomycosis, a condition in which endospores are found. No endospores were found in this case. Moreover, the average size of the organisms in the sections was that of Blastomycetes and not of Coccidioides. A further aid in diagnosis is a positive skin test to the Blastomyces vaccine and a positive complement-fixation test. These were not done in this case. It is felt by some authorities that the prognosis is best with a positive skin test and a negative complement-fixation test, and the prognosis poor with the opposite situation[5].

Treatment of this disease has been disappointing, except in cases in which only skin was involved; in these cases surgery, iodides, and roentgen therapy have been of considerable benefit. Numerous drugs have been used in the treatment of systemic blastomycosis, including arsenicals, colloidal gold and copper, thymol, sulfonamides, and ether, as well as roentgen therapy and antibiotics. The most consistently good results have been with iodides, usually given orally as a saturated solution of potassium iodide in large doses. Schoenbach, Miller, Ginsberg, and Long[3] have reported good results in two cases of systemic blastomycosis in which stilbamidine and propamidine were used and the same authors[4] reported good results in three out of four patients treated with stilbamidine. The few articles which have appeared on the use of antibiotics have reported consistently poor

results with streptomycin, penicillin, chloromycetin, and aureomycin. Potassium iodide is probably still the most effective treatment, but the importance of skin-testing with Blastomyces vaccine before instituting potassium iodide therapy is repeatedly stressed in the literature. Several cases have been reported in which a cure or improvement has been obtained with potassium iodide, but in view of the recent reports on stilbamidine it would seem that this drug deserves a thorough trial.

NOTE: The author is indebted to Dr. Joseph Porter and the Pathology Department of the Maine General Hospital for their invaluable aid and cooperation in this case.

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COMPRESSION ARTHRODESIS OF THE KNEE JOINT

A CASE REPORT

BY C. J. KAPLAN, M.CH.ORTH., F.R.C.S. (ENG.), DURBAN, SOUTH AFRICA

From King George V Hospital, Durban

The positive and reliable results of arthrodesis of the knee joint by the method described by Key[2,3] and later by Charnley are well known to most orthopaedic surgeons. This method has been employed by the writer in seven cases with uniformly good results. In three cases the operation was performed for osteo-arthritis and in four for tuberculosis of the knee joint.

In an early case the tibial pin fractured on the tenth day after operation and examination revealed that the knee was clinically firm. Since then it has been our practice to commence straight-leg-raising exercises two weeks after operation and to remove the Steinmann pins one week later and to fit the patient immediately with a walking caliper brace which had been ordered a week previously. Walking is begun on the following day and the patient is ready to leave the hospital within seven to ten days. The caliper is discarded after three months, but it is likely that this period can be shortened without danger.

A unique opportunity was offered to obtain a postmortem specimen of a knee joint exactly forty-two days after arthrodesis had been performed. The findings are instructive.

CASE REPORT

An Indian male, aged thirty-two years, underwent a compression arthrodesis for tuberculosis of the left knee with unsound fibrous ankylosis and backward subluxation of the tibia on the femur. There was a long history of pulmonary tuberculosis, but this was declared to be under control at the time of operation.

On the fourteenth day after operation the sutures were removed and straight-leg-raising exercises were commenced.

On the twenty-first day the Charnley clamp and pins were removed and the patient was fitted with a walking caliper brace. On the twenty-eighth day he was walking well without pain.

On the thirty-sixth day after operation the patient went to bed, not feeling well; no cause was found. On the forty-second day the patient died suddenly.

Autopsy revealed lesions of both apices, adherent pericarditis from an old tuberculous infection, and atheroma of the coronary arteries. The cause of death was certified as heart failure, due to coronary insufficiency.

FIG. 1

Fig. 1: Mounted specimen, showing intimate contact between the two bones.

Fig. 2: Roentgenogram of slice six millimeters thick, showing density along the line of arthrodesis.

FIG. 2

FIG. 3

Microscopic section (van Gieson stain, × 16) showing apposition of bone trabeculae. In this technique the slide was used as a negative and projected on a sensitized plate, from which this photograph was made.

The knee itself was firmly united and no impression could be made upon it by levering it over the edge of the table. The knee region was excised *en bloc* and sagittal sections were made. A central section, six millimeters thick (Fig. 1), showed intimate bony contact between the two fragments. A roentgenogram of this slice showed increased density along the line of contact (Fig. 2).

Microscopic sections were cut through the line of the arthrodesis and stained by the Mallory technique. Figure 3 shows this section and indicates the complete absence of dead space between the bone ends. High-power views (Figs. 4 and 5) show marked osteogenesis, with repair going forward rapidly. Figure 4 shows definite bridging of the gap with woven bone which appears to "flow" away from its parent bone.

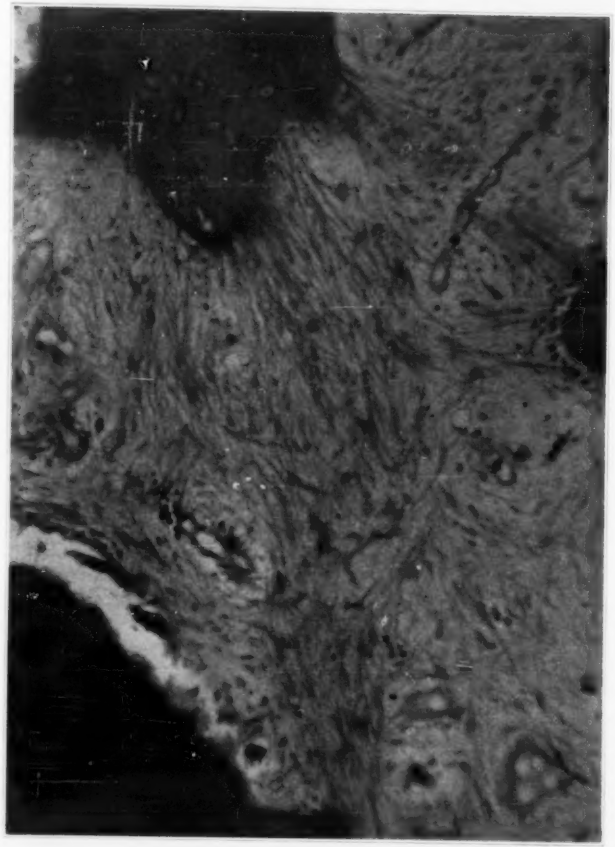

FIG. 4

FIG. 5

Fig. 4: Photomicrograph (Mallory stain, × 160) of section decalcified by electrolytic method, showing fibrils of woven bone flowing out from a trabecula to cross the line of arthrodesis.

Fig. 5: Photomicrograph (× 160) of another field, showing active osteogenesis. The lamellar structure of mature bone is well shown.

DISCUSSION

The rapid and sure bony union following this method of arthrodesis is a great advance when compared with other methods, which require changes of plaster whenever needed over periods of six to nine months and which offer the ever-present threat of fibrous union.

In arthrodesis without compression, as in ordinary fracture healing, the dead space between the fragments is filled with a hematoma which becomes vascularized and organized by the ingrowth of capillary loops; around this forms the osteoid tissue which eventually becomes bone by a process of metaplasia. The compression factor in arthrodesis ensures complete immobility and close contact of bone ends, eliminating the need for the vascular framework, and allows immediate growth of fibrils of woven bone from the marginal osteoblasts with resultant firm and early bony union.

NOTE: The author wishes to thank Mr. S. Scott of King George V Hospital, Durban, for mounting the specimen, Miss Alice Solomon for the microscopical preparations, and Mr. R. A. Mansfield for the excellent photographs.

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GRAVITY GONIOMETER

BY ROSWELL K. BROWN, M.D., AND B. R. STEVENSON, PH.D., BUFFALO, NEW YORK

From the Edward J. Meyer Memorial Hospital and The University of Buffalo School of Medicine, Buffalo

The gravity goniometer is an instrument for the measurement of angles by means of a protractor with a weighted pointer. The Physiotherapy Department of Murphy

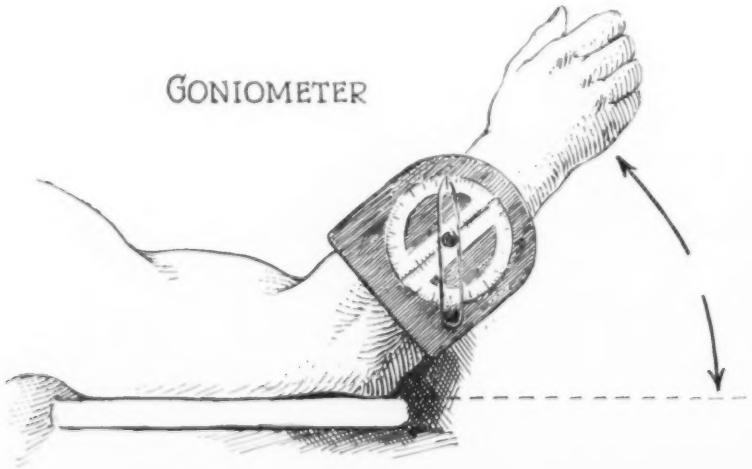

FIG. 1-A

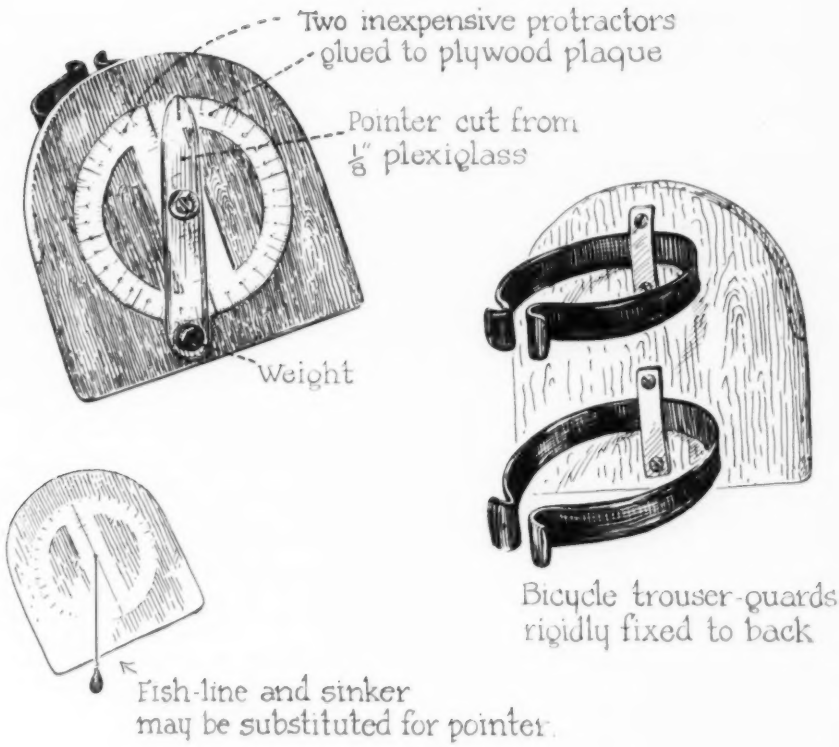

FIG. 1-B

General Hospital (United States Army) called to our attention a gravity instrument used in pronation and supination. The improvised instrument shown in the illustration is more widely useful. The bone proximal to the joint must be fixed for two readings at the extremes of distal motion. The face of the instrument must move in a vertical plane. The use of a protractor and a weighted string is simpler and affords a ready check on the perpendicularity of the protractor face.

A SIMPLE METHOD OF REDUCING DISLOCATIONS OF THE ELBOW JOINT

BY LEROY S. LAVINE, M.D., BROOKLYN, NEW YORK

From the Departments of Orthopaedic Surgery, Jewish Hospital of Brooklyn, Brooklyn, New York, and Indiana University Medical Center, Indianapolis, Indiana

Backward dislocation of the elbow joint is a common injury and may occur at any age. The usual method for reducing this dislocation involves the use of an assistant who holds the upper portion of the patient's arm while the operator applies gentle traction to the patient's forearm in line with the deformity. Occasionally, this method of reduction

fails. This is true especially when patients have lateral or medial displacement or when patients are in a state of apprehension, causing muscle spasm. In such occasional instances of failure, reduction under anaesthesia is generally resorted to.

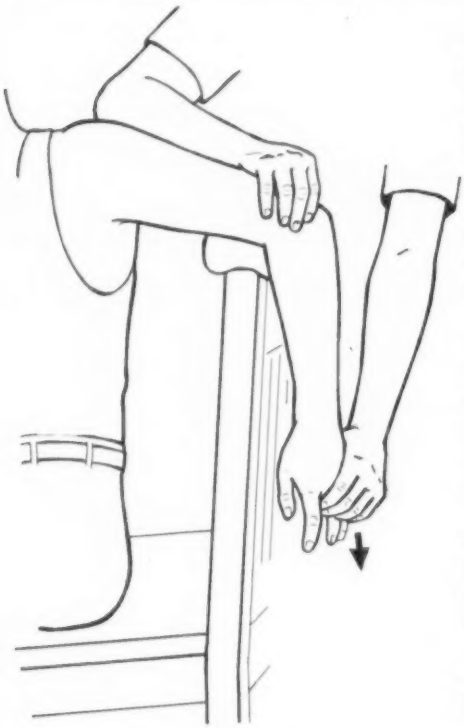

FIG. 1

The author's method for reduction of a backward dislocation of the elbow joint is simpler than the one generally in use, because it obviates the necessity of an assistant. Additionally, this method eliminates the likelihood of even the occasional use of anaesthesia by the employment of what might be termed psychotherapeutic muscle relaxation instead of anaesthetic relaxation, a procedure undoubtedly more desirable for both the patient and the physician.

The author's method was discovered accidentally while he and a patient, a child, were waiting for anaesthesia in order that a dislocation defying simple reduction might be reduced. The child's arm had been placed in a comfortable position over the back of a chair and had been in that position for five or ten minutes. The patient appeared so relaxed that the operator walked by and pulled down on the patient's fingers, immediately reducing the dislocation atraumatically (Fig. 1).

A roentgenogram revealed perfect position. The usual postoperative care was followed with excellent results.

This method of reduction seemed so simple that it was utilized, successfully, on six succeeding patients, three of whom were adults and two of whom had lateral displacement. The method was slightly modified by placing one hand on the patient's humerus and pulling on the patient's entire hand with the other, the operator's thumb being used to correct the lateral or medial displacement during the pulling down.

Padding may be placed over the back of the chair under the patient's arm before reduction in order to ensure the patient's comfort.

It should be emphasized that it is necessary, in order that the procedure may be effective, that the patient be relaxed. The dislocation can then be reduced gently with as little trauma as possible. A relaxing factor inherent in this method is that the patient's arm is left completely under the control of the patient until the moment of reduction. The presence of one operator rather than of two seems also to create a tension-free atmosphere. The patient should first be assured that he will suffer little pain or discomfort. This will help to gain the patient's complete confidence which is so important in all methods of non-anaesthetic reduction of dislocation.

Proceedings

WESTERN ORTHOPEDIC ASSOCIATION

Sixteenth Annual Meeting held at Coronado, California

OCTOBER 16 TO 18, 1952

In this delightful setting on the shores of San Diego Bay, some four hundred members, their guests, and members of their families gathered to learn about the contributions which the orthopaedic men of the western United States are making to the specialty of bone and joint surgery. With equal enthusiasm, old friendships were strengthened, better acquaintance developed, and the social activities were a delight to all.

Sun Valley was overwhelmingly voted as the choice for the next Annual Meeting in the fall of 1953, under the presidency of Dr. John LeCocq of Seattle, Washington. Other officers elected to guide the Association for the year were:

President-Elect: Dr. Leonard B. Barnard, Oakland, California;
Secretary: Dr. Forrest L. Flashman, Seattle, Washington;
Treasurer: Dr. Harry C. Leavitt, Seattle, Washington;
Chairman, Editorial Committee: Dr. Merrill Mensor, San Francisco, California;
Chairman, Program Committee: Dr. Ernest Burgess, Seattle, Washington;
Chairman, Entertainment Committee: Dr. E. A. LeCocq, Seattle, Washington;
Chairman, Exhibits Committee: Dr. Edgar Rogge, Seattle, Washington.

The daily scientific sessions started promptly at 9:00 o'clock in the morning and carried through until 5:00 o'clock, with the usual mid-day interruption for lunch and periods to visit the commercial exhibits. These interesting exhibits were quite representative of the national surgical houses and, with the display of their latest gadgets, attracted considerable attention.

The report of the retiring president, Dr. Vernon P. Thompson [1] of Los Angeles, California, was typical of the idealism, clear thinking, and leadership of one of the outstanding members. He traced the growth of the Association from its founding in 1933 to its present status, as the representative of orthopaedic thought and progress of the western United States, with its concomitant responsibilities to the young man starting the specialty, and its obligations to the national organizations and the orthopaedic profession in general. An abstract of the Presidential Report follows:

The Presidential Report. DR. THOMPSON[1], after giving credit to the other officers of the organization and to members of the various committees for their good work and cooperation, reviewed the history of the Western Orthopedic Association and outlined its purposes. He recalled that the Association was first organized in 1933 and was an outgrowth of the annual exchange meetings between the Los Angeles and the San Francisco Orthopaedic Societies, which had been in existence for many years. There has been a steady growth and expansion of the Association into new areas, with the formation of many new chapters; in addition to the chapters in Los Angeles, San Francisco, and San Diego there are chapters in Washington, Oregon, Arizona, Utah, and Hawaii. The Honolulu Chapter, the newest chapter, and its representative to this year's meeting, Dr. J. Warren White, were welcomed into the organization.

The purposes of the organization are both scientific and social and a proper balance between these two was urged. In some years the scientific aspect of the program has been somewhat top-heavy and in other years the social aspect has received more than its proper share.

Dr. Thompson made several recommendations for the future which included:

1. The employment of a part-time executive secretary;

2. A central office where the records could be kept and where much of the business of the organization could be transacted;

3. That more emphasis be placed on the non-operative aspect of orthopaedics. We probably have been guilty of neglecting this aspect of our specialty in recent years to the extent that other fields are taking over certain orthopaedic problems;

4. An award to be given each year for the best essay submitted by an orthopaedic resident physician. (Later in the meeting this recommendation was adopted by the membership, and it is planned to give a $500.00 award each year for the best essay by a resident physician in orthopaedic surgery. The award will be known as the Vernon P. Thompson Award.)

The scientific papers, numbering twenty-seven in all, are summarized in the following abstracts:

Use of Quick-Setting (Self-Curing) Acrylics in Orthopaedic Surgery. DR. L. L. WILTSE[2] and DR. R. H.

[1] 1136 West Street, Los Angeles 14, California.
[2] 117 East Eighth Street, Long Beach 13, California.

HALL[3]. Methyl methacrylate, an acrylic plastic, has been used for many years in medicine but especially in dentistry. The clear plastic used in the Judet prosthesis is methyl methacrylate, also called lucite.

The authors have developed a quick-setting acrylic, which is methyl methacrylate, to the powder of which a catalyst, benzoyl peroxide, has been added and the accelerator in the liquid is a small quantity of a tertiary amine. The larger the amount of catalyst and accelerator added, the faster setting will occur. A detailed description of the technique of mixing the materials was given. As the material sets, the temperature rises very rapidly and will go up to 176 degrees Fahrenheit. Hence, when placed in living tissues, necrosis will result unless ice-cold water is run over the material. The self-curing acrylic is less strong than lucite but, with slight re-enforcing with steel pins, no breaking occurs. The liquid is also self-sterilizing.

Reactions to the acrylic were studied in rabbits and monkeys and it was found to produce more reactions than Vitallium. Cranial defects in animals were filled successfully. It was also used in studying prosthetic replacement of various joints in monkeys.

The authors believe that this acrylic may be found of use in the treatment of many orthopaedic conditions.

Reconstruction of the Distal End of the Femur with the Use of an Acrylic Prosthesis. DR. GEORGE L. KRAFT[4] and DR. D. H. LEVINTHAL[5] presented a case in which a pathological fracture of the femur due to giant-cell tumor had occurred in the supracondylar area. The patient was a white female, thirty-seven years of age.

An acrylic prosthesis had been made exactly the same size as her uninvolved femur on the opposite side. The whole lower end of the femur was then removed and the acrylic prosthesis was substituted. The operation was done in December 1951; weight-bearing in a cylinder was permitted four weeks after surgery and weight-bearing with no external support nine weeks postoperatively. Flexion in the knee about nine months later was 75 degrees and painless. Shortly thereafter the prosthesis cracked.

Dr. Kraft now has made a new prosthesis, which he claims will not break. He is of the opinion that probably metal re-enforcements may actually weaken a prosthesis rather than strengthen it.

Complications Following Replacement Arthroplasty of the Hip. DR. HOWARD A. MENDELSOHN[6] and DR. SEYMOUR L. ALBAN[7] reported on the study of forty patients ranging in age from twenty-five to eighty-three years. Total number of prostheses used was forty-five, including thirty-nine Judet or modifications of the same, five Eicher and one Jaenichen-Collison. Twenty-four or 60 per cent. of the patients had one or more complications. The various prostheses were used for degenerative arthritis, recent intracapsular fractures, old intracapsular fractures, aseptic necrosis of the femoral head, and rheumatoid arthritis. Complications were many; deaths 10 per cent., dislocations 11 per cent., superior subluxations 22 per cent., paracapsular calcifications 20 per cent., pain at site of stem protrusion 8 per cent., protrusion of Eicher stem through the cortex 5 per cent., varus deformity of prosthesis 5 per cent., fracture of femur 5 per cent., fracture of acrylic head 2.5 per cent., persistent pain 37 per cent.

The authors believe that postoperative dislocations are probably due to (a) insufficient length of the femoral neck; (b) inadequate depth of the acetabular cavity; and (c) excessive valgus placement of the prosthesis. They warn that surgeons must have a critical awareness of the many hazards involved in this procedure.

Open Reduction and Internal Fixation of Ununited Fractures of the Neck of the Femur. DR. HARRY R. WALKER[8] and DR. DOUGLAS D. TOFFELMIER[9]. Dr. Walker stated that the greatest contribution to treatment for fractures of the femoral neck was made by Royal Whitman with his abduction treatment. For a time it was believed that failures were rare, but subsequent studies showed that in only 53 per cent. of patients did osseous union develop by this method of treatment. Since the introduction of internal fixation, osseous unions have materially increased. However, because of the structure of the bone in this region, and the inadequate blood supply, there will inevitably result a great percentage of non-unions. The speaker seems to prefer the Brackett operation if the femoral head is viable. Moreover, the Brackett operation and the bone-peg operation may be combined; the head is removed from the acetabulum and is placed on top of the denuded trochanter and held by a bone peg, made from a four-inch tibial graft, which is driven through a drill hole made in the head and down through the trochanter and into the medullary canal of the femur. The danger in this procedure is that the viability of the head may be impaired. Dr. Walker employs the various reconstruction operations of Albee, Whitman, Colonna, Campbell, or Luck in the presence of non-viable heads.

Twelve cases were reported with very good end results in eight.

Following Dr. Walker's paper, Dr. Toffelmier stated that orthopaedic surgery goes through eras, spasms,

[3] 117 East Eighth Street, Long Beach 13, California.
[4] 4418 Vineland Avenue, North Hollywood, California.
[5] 4418 Vineland Avenue, North Hollywood, California.
[6] 450 North Bedford Drive, Beverly Hills, California.
[7] 450 North Bedford Drive, Beverly Hills, California.
[8] 354 21st Street, Oakland 12, California.
[9] 354 21st Street, Oakland 12, California.

or fads. He recalled the era of the various methods of internal fixation for hips; Whitman, Smith-Petersen, and now the reconstructive era. This has been the subject of great discussion. Something valuable has been learned from each case. The era in which we now are brings in metals, plastics, and new complications.

Motion pictures were shown of several patients, in all of whom non-union developed; eventually reconstruction operations were necessary.

Acetabulo-Arthroplasty by Concentric Articulation Methods. Dr. Roger Anderson[10] and Dr. Ivan Loughlen[11] stated that the relief of acetabular pain, stiffness, and malformation in arthroplasties, as well as prosthetic surgery, can be accomplished by strict adherence to the following principles:

1. Complete removal of all diseased cartilage, osteophytes, and fibrocartilaginous overgrowths;
2. Preservation and utilization of the durable subchondral bone;
3. Conformity of the axis of the acetabulum with the axis of the femoral neck and head;
4. Perfection of fit between the head and the socket;
5. Correction of contractures — synovial, capsular, and muscular; and maintenance of corrected position.

To fulfill these requirements, a technique of acetabular reconstruction was devised which is equally effective with Vitallium-cup and fascial procedures, or with any of the various prostheses.

In the discussion following the presentation of these five papers, Dr. James McCloy[12] said that today there is no universal hip prosthesis. Perhaps the ideal prosthesis will be interchangeable and adjustable. The ideal prosthesis will enable us to adhere to the time-proven principles of arthroplasty if these principles are of any value at all.

When a Vitallium cup settles on the neck and becomes fixed, the patient's pain subsides. This fixation of the prosthesis to the femoral neck may partially explain the early and prompt freedom from pain seen with the use of the new acrylic and metallic replacements.

To be successful, a prosthesis must have the broadest possible surface contact on bone, without hindering blood supply, and should bear weight with a minimum of stress if pressure atrophy is to be avoided.

It is now readily seen that a prosthesis should be chosen to suit the problem at hand. Several types and sizes should be conveniently available. The Judet type, even with added washers, is certainly not suitable for use in the patient with a short femoral neck. Vertical stresses cause such prostheses to go into varus eventually and gluteal weakness always ensues. For the short femoral neck, the use of an intramedullary type of prosthesis is recommended, which does not require resection of the neck and trochanter for its insertion; for, if infection follows, the problem is then not greatly increased. The metal can then be removed and the remaining neck can be placed in the acetabulum. There are other types available for use in the total absence of the femoral neck and, in fact, some forty types have now been reported in use.

In his small group of cases, he has found that the posterolateral incision is the most suitable for these operations. The danger of postoperative dislocation is reduced. The blood loss is diminished and the procedure is definitely less time-consuming. Moreover, the lateral aspect of the femur can be visualized without a second incision.

In reference to reconstruction operations, osteotomy has been used a little more frequently than the formerly more popular formal reconstructions. It has been generally thought that the Brackett and Luck procedures are more applicable to the younger patient for whom a grafting operation is not suitable because of a short or non-existent femoral neck, in the presence of a viable head.

With better understanding of the indications for the use of the hip prosthesis and with a more judicious choice of the type of prosthesis to be used on a given occasion, we will see a definite diminution in the number of complications so ably discussed in today's papers.

Dr. Fraser MacPherson[13] said that the preceding papers present many interesting and possible new approaches to the treatment of hip conditions.

As one of the speakers pointed out, amputation is a destructive process. Arthrodesis is an excellent procedure, resulting in relief of pain, but there are still many complications. We are trying to be more constructive. Dr. Mendelsohn has shown the complications which arise in any arthroplasty; his report is discouraging, but arthroplasty may be a stage such as we went through in pinning hips. We are using the Hibbs approach because it is the easiest approach we know, with very little loss of blood and much less shock.

Dr. Anderson brought out anatomical problems which are important. Many mistakes are made in operating upon short necks. It is important to restore the neck and to have the acetabulum of adequate size. His principles emphasize the problems of adequate tension about the hip.

The Pitfalls of Contrast Myelography. Dr. John D. Camp[14] said that myelography is now established as

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a diagnostic procedure; it is a mechanical procedure, in which we try to outline the form of a substance within the spinal canal. It is essential to correlate clinical and myelographic examinations.

Five cubic centimeters of contrast media is advised, especially in the thoracic and cervical regions, although even in the lumbar region it is advisable to use at least five cubic centimeters because the contrast media should be run up at least to the twelfth thoracic vertebra and preferably to the tenth thoracic; with a smaller amount than five cubic centimeters in any of the three spinal regions, the tendency to droplet formation rather than formation of a solid column is great, and multiple as well as small lesions are missed.

The common anatomical pitfalls are:

A. A narrow *cul de sac*, which occurs in 5 per cent. of the patients;

B. Failure to observe the number of the lumbar vertebrae, which may be four or five;

C. Variation in the shape of the vertebral bodies, which are sometimes scalloped; in such cases the oil shows multiple shadows which might simulate multiple protruded discs with the oil column becoming narrow as it passes over the hump of the intervening discs.

In *A*, which accounts for 5 per cent., it is obvious that either small or large lesions will not show because of the variation.

In *B* it is essential that roentgenograms be taken prior to the myelograms so that the number of the vertebrae may be definitely known.

In *C* multiple views, including a lateral and a prone horizontal, in addition to the conventional views, are very helpful, since 18 per cent. of the discs appear to be multiple.

The technique of puncture is most important; the procedure should be without bleeding and with an easy introduction of the contrast media after the appearance of spinal fluid, as oil in the epidural space will not move. In the sub-arachnoid space, on fluoroscopy the oil will move faster than in the sub-dural space and a combination of these causes misleading types of deformity.

Central discs are difficult to recognize, because most of them do not cause obstruction. If the table is tilted slowly, and multiple views are taken, a large disc can readily be determined, although it may simulate a tumor as a bilateral defect. Hypertrophic spurs are also misleading and multiple views are helpful in identifying them. Combinations of herniated disc and tumor masses frequently occur, and it must be remembered that only 2 per cent. of spinal tumors occur in the lumbar region, and that of all cord tumors 4 per cent. are multiple. Obviously, atrophic lesions which do not occupy space are not disclosed by myelography.

Contrast myelography is a mechanical method, and it is essential to correlate these findings with the clinical findings. Dr. Camp estimates that there is approximately 20 per cent. of error in contrast myelography. The slides shown were of individual cases illustrating all of these pitfalls.

Fundamental Studies on Electromyography. Dr. Verne T. Inman[15] reported an experiment attempting to demonstrate the existence of the percentage of a simple relation between electromyogram and tension, and using the human muscular activity in cineplastic amputees, where the tension and electric behavior of individual muscles could be measured simultaneously. The strain-gauge dynamometer and the Heiland oscillograph were used with three types of electrodes—skin, wire, and co-axial—and readings were recorded simultaneously.

It should be noted that the type of electrodes employed is not essential, if they are placed over the central mass of the muscle to be studied. The results of the experiment showed:

1. The integrated electromyogram parallels tension in the human muscle contracting isometrically.

2. No quantitative relation between electromyogram and tension exists when the muscle is allowed to change in length.

3. No quantitative relationship between electromyogram and muscle powers exists.

4. The amplitude of the electromyogram characteristically diminishes in large human muscles when they are stretched. This phenomenon has not been fully explained.

5. It is shown that a lag of approximately 0.08–0.02 second exists between peak electrical activity and peak tension of the human muscle, which should be taken into account in the analysis of rapid movements.

Electromyography in Relation to Orthopaedic Surgery. Dr. A. A. Marinacci[16] emphasized that it is necessary to keep in mind that the ultimate unit of power is called a motor unit; that a motor unit is a nerve and a muscle working as a physiological machine generating power, resulting in voluntary function; and further, that a motor unit anatomically is made up of one anterior horn cell, its axon, and approximately 100 to 150 muscle fibers. Thus, by voluntary effort, it is possible to generate a single motor-unit voltage, which has one to three or four spike-wave forms with a variation of voltages from 200 to 3,000 microvolts, having a duration of from 2 to 10 milliseconds with a generation frequency of from 1 to 30 per second. Further, under normal conditions, the action potential makes muscle fibers contract in harmony, and the result is a sharp clear sound.

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[16] 1200 North State Street, Los Angeles, California.

The method of diagnosis of peripheral-nerve injury in the form of complete or partial interruption, irreversible physiological block, or psychological block was shown. The use of the electromyograph as a diagnostic aid in herniated intervertebral discs and their differentiation from disease processes was discussed. The Meditron Clinical Electromyograph was demonstrated, in which the various wave forms were heard through the loud speaker and seen in the oscilloscope.

Electromyography was recommended as a laboratory procedure, to be correlated with the clinical picture.

Electromyography in the Diagnosis of Nerve-Root Compression Syndrome. Dr. Paul A. Shea[17], Dr. Ward W. Woods[18], and Dr. Delbert H. Werden[19] reported the results of a study in seventy-five consecutive cases to determine whether lesions compressing a single spinal nerve root could be located exactly with the more accurate technique of using needle electrode and cathode-ray oscilloscope, and the accuracy of electronic diagnosis as compared with that of pantopaque myelography. The results have been verified surgically. The instrument used was a Meditron, Model 201, Clinical Electromyograph. The results showed correct localization by the electromyogram of the spinal nerve root or roots compressed in sixty-eight of seventy-five cases.

A comparison between electromyographic and myelographic and operative findings revealed that the electromyograms were correct in sixty-eight of seventy-five cases or 90.7 per cent., incorrect in seven cases or 9.3 per cent; the myelograms were correct in fifty-eight of seventy-five cases or 85.3 per cent., incorrect in ten or 14.7 per cent.

It is suggested that the use of electromyography in conjunction with clinical examinations and myelography results in more accurate diagnosis in cases of spinal-nerve-root compression syndrome.

In the discussion of the preceding four papers, Dr. Charles O. Bechtol[20] brought up the question of the practical use of the electromyograph to the orthopaedist. It is strictly a laboratory procedure to help in diagnosis of nerve-root pressure and in watching the progress of a known nerve lesion. Further study will increase its usefulness, but it is not yet an essential part of the orthopaedist's armamentarium.

Dr. Francis West[21] believes that the procedure is a definite aid in diagnosing nerve-root pressure but has great possibilities of error. It helps in localizing the level of the lesion. In questionable cases, a negative finding is of extreme value.

Turnbuckle Cast for Reduction for Wide Separation of Symphysis Pubis. Dr. Robert A. Roback[22], and Dr. Harry J. Hogan[23] stressed that several methods are available for reducing fracture-dislocations of the pelvis with separation of the symphysis pubis. Fresh fractures are usually easily reduced; however, after several weeks of separation, the pubis is not easily realigned. Two such cases were reported: one in a patient with multiple fractures of both lower extremities with 2.5 centimeters separation of the symphysis after five and a half weeks, reduced by turnbuckle cast to 11 millimeters with complete functional recovery; the second, a patient seen two months after the injury, in whom the separation was reduced by a similar method to 12 millimeters with asymptomatic ambulation possible.

Discussion by Dr. Robert Mazet, Jr.[24] pointed out that the separation between the symphysis pubis which had persisted for several weeks contrasted to fresh separation. He cited a single case, a machinist, fifty-nine years old, with fracture of the right femoral neck, fracture of the scapula, fracture of the pelvis with separation of the symphysis pubis, and rupture of the bladder.

After prompt repair of the bladder, a pelvic sling was applied in the conventional manner. Complete reduction was obtained within twenty-four hours.

Hip Derangements Seen in Cerebral-Palsied Children. Dr. Sydney Sperling[25] stressed the fact that in spastic children careful observation should be made of the hip joints, because so many tend to have a migration of the femoral head out of the acetabulum. The factors producing this are probably the tight adductors and the flexion and internal rotation, thus predisposing to migration of the femoral head.

Of 1,243 patients seen in the Cerebral Palsy Clinic over a six-year period, 162 were referred for roentgenograms of the hips because of suspected bone changes on clinical examination. Of these 162 children, thirty-two were found to have hip abnormalities consisting of frank dislocations, subluxation of femoral heads, and valgus positions of the femoral head.

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[22] Wadsworth Hospital, Veterans Administration Center, Los Angeles, California.
[23] Wadsworth Hospital, Veterans Administration Center, Los Angeles, California.
[24] Wadsworth Hospital, Veterans Administration Center, Los Angeles, California.
[25] Children's Hospital, Los Angeles, California.

Treatment consisted in tenotomy of the adductor longus and neurectomy of the anterior branch of the obturator nerve. Postoperatively, mild traction was applied in wide abduction, and later an abduction night splint was used. In six selected patients improvement in ambulation and ability to stand were achieved.

In the discussion of this paper, DR. WILLIAM R. DUNCAN[26] stated that he believes that the early valgus position of the femoral neck is a danger sign that the femoral head may dislocate, that the adductor spasticity is the cause of the valgus position of the neck, that the rectus femoris is frequently contracted in these cases, causing flexion of the hips and forward tilt of the pelvis, and that this combination produces the subluxation of the femoral head and eventual dislocation.

DR. J. WARREN WHITE[27] believes in doing the intrapelvic obturator neurectomy in these cases. He also advocated subtrochanteric osteotomies to correct the deformity.

DR. SAMUEL MATHEWS[28] stressed the tendency of many surgeons to pass the problem to the "next" man. The cause is the fixed position of flexion and adduction, resulting in constant stretching of the capsule, coupled with valgus position of the femoral neck. He urged the watching for progressive luxation, but he is uncertain whether myotomies and neurectomies are sufficient. He emphasized the necessity of maintaining the abduction position.

Tibial-Plateau Fractures. DR. MASON HOHL[29] reported a study of 345 patients treated at the Los Angeles County Hospital between July 1944 and June 1950, the cases being divided into three groups:

A. The type in which the entire plateau appears to slide laterally and becomes depressed without much articular surface damage;

B. The type in which depression of a portion of the condyle is the main feature;

C. The split type in which lateral displacement is noted.

Of all of these cases surgery was done in only twenty-one cases. Traction or casts were used in the remainder. Follow-up was for a period of two or more years, average follow-up was four years.

In the patients operated upon, iliac bone or tibial bone was used to fill the defect after elevation.

The results show that closed treatment will give satisfactory results in 85 per cent. of cases with nine millimeters or less of depression. Operative treatment is recommended with depressions of more than one centimeter, and in 87.5 per cent. of these satisfactory function was obtained; whereas in those depressed more than one centimeter and treated conservatively, only 45 per cent. obtained satisfactory end results. Early motion is stressed in the treatment, as well as the need of keeping the femoral condyle out of the depressed area until it is well filled in with fibrous tissue.

Of the entire series 74 per cent. attained excellent or good results functionally.

Traumatic Subcutaneous Rupture of the Tibialis Anterior Tendon. DR. GEORGE L. ORDWAY[30]. This is a rather rare condition and the author stated that only ten cases have been reported in the literature.

Two cases were reported by the author. Both patients sustained the rupture when strong plantar flexion of the foot occurred at the time of the accident. Surgical repair was done in both cases with excellent functional results. Stainless-steel wire for suturing the tendon is recommended as an ideal atraumatic material to decrease foreign-body reaction and serous formation.

In the discussion DR. MERRILL C. MENSOR[31] said that he believed that probably more cases occur than are recognized; careful search should be made for rupture of the tibialis anterior in trauma of the foot. Early recognition and repair are important for a good end result.

Hyperextension Deformity of the Proximal Interphalangeal Joint. DR. ROBERT B. PORTIS[32] reported that an unhealed avulsion of the palmar capsule of the proximal interphalangeal joint of the finger leads to a characteristic deformity and disability. The finger cannot be fully extended since, by the rupture of the volar capsule of the joint, the proximal interphalangeal joint hyperextends and the distal joint falls into partial flexion. Hyperextension of the proximal interphalangeal joint is accompanied by herniation of the head of the proximal phalanx through the avulsed capsule. These injuries generally are produced by a blow on the tip of the finger.

Surgical correction is by repair of the avulsed volar capsule. He reported four cases. Upon one patient he operated with good result.

In the discussion DR. WALTER C. GRAHAM[33] reported having seen many similar cases, but he did not agree that the capsule is always torn. In many he found that the capsule was simply stretched, and occasionally the lateral bands were torn near the edges. He believes that the problem requires further investigation.

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[29] Los Angeles County Hospital, Los Angeles, California.
[30] Stanford University Hospital, San Francisco, California.
[31] 490 Post Street, San Francisco 2, California.
[32] 450 North Bedford Drive, Beverly Hills, California.
[33] 1421 State Street, Santa Barbara, California.

Transplantation of the Greater Trochanter for Rotational Deformities of the Lower Extremity. Dr. William R. Duncan [29] stated that, although internal rotational deformity is encountered more often in the spastic type of cerebral palsy, it is also encountered in non-spastic children who exhibit a great deal of internal rotation of one or both lower extremities when they walk. This is caused by the greater trochanter being placed too far posteriorly and, on external rotation of the extremity, the posterior portion of the trochanter impinges against the pelvis. With the hip flexed, external rotation of the hip is not restricted, because in that position the posterior part of the greater trochanter will not impinge against the pelvis.

Correction is obtained surgically by transplanting the greater trochanter forward through a posterolateral approach. Denis Browne splints are used to hold the correction postoperatively until full healing has occurred. Several cases were reported with satisfactory end results.

Dr. Kenneth B. Jacques [31], in discussing the paper, said that he had not noticed this deformity in children except in spastics. He believed that a good deal could be done to train children in proper postural habits to avoid this condition.

A Critical Analysis of End Results in Fractures of the Femoral Shaft Treated by Intramedullary Nailing. Col. Ernest A. Bray [35] stated that during the past four years at Letterman Army Hospital there have been ninety-three open intramedullary-nailing operations performed in selected fractures of the middle three fifths of the femoral shaft. In eighty-five of these patients there has been sufficient follow-up to know the end result. Of this group, sixty-five operations were for recent fractures,—fifty-two for closed fractures and thirteen for open fractures. Twelve operations were performed because of old non-union of the femur. Associated iliac-bone grafts were used in all non-unions and in almost all patients with recent fractures. Eight patients were considered separately, because they presented infected gun-shot fractures with marked comminution and loss of bone. These patients were treated by thorough wound débridement and intramedullary nailing; all wounds were left open for drainage. In regard to the time of weight-bearing after operation, the earliest was one week, the latest sixteen weeks and the average 5.2 weeks. The average period of time in bed was 3.6 weeks, being 2.7 in recent fractures, 7.7 weeks in the non-unions. A chart was presented, comparing the patients treated conservatively with the patients treated by intramedullary nailing. For the patients treated conservatively, the time in bed was an average of twenty-five weeks and for the patients with intramedullary nailing, the time in bed averaged 3.6 weeks. The time in hospital was 44.1 weeks for those treated conservatively and 22.7 weeks for those treated by medullary nailing. Primary bony union occurred in 81 per cent. of the patients conservatively treated, in 98.5 per cent. of the recent fractures treated by medullary nailing, and in 94.1 per cent. of the entire group treated by medullary nailing. One non-union occurred in a patient treated by medullary nailing, because the pin was removed at seven months, which proved to be too early. Colonel Bray emphasized that the nail should remain in place for a minimum time of one year.

In conclusion, the author stated: "Our very satisfactory results with this group of patients have not made us unmindful of the precautions essential to the nailing procedure and the inherent dangers of the method. Patients must be carefully selected and the operations performed by experienced surgeons under optimum conditions. Gunshot fractures should be treated in this manner only under exceptional circumstances and these wounds must be left open. When properly applied and skillfully executed, the intramedullary-nailing procedure has proved to be an historic advance in the treatment of fractures of the femoral shaft. The tremendous functional and economic advantages over treatment by conservative measures are sound justification for the calculated operative risk."

In the discussion, Dr. Leonard Barnard [36] recalled our attitude toward the World War II German prisoners who were returned to their own countries with an "iron bar" in the femur. We called the procedure a terrible war atrocity. It is Dr. Barnard's opinion that the treatment of choice for fractures of the femoral shaft is intramedullary pinning; he states that this is the method he would want used upon himself if he had this type of fracture.

Well-Leg Countertraction, Application, Mechanics, and Indications. Dr. J. Warren White [37] said that the well-leg countertraction concept was popularized two decades ago and inappropriately termed "well-leg traction". However, the technique was advocated as early as 1826; in this century it has been popularized by Hoke, Anderson, Jones, and others. Dr. White praised the apparatus of Roger Anderson, but demonstrated a hospital-made apparatus which is inexpensive and can be made quickly and easily with crating wood and other materials available in any hospital. Roger Anderson was the first to use a transfixion pin on the affected side. Dr. White emphasized that he had found it advantageous to use a transfixion pin on both the well and the affected sides. A toe-to-groin cast is applied to each lower extremity, incorporating the transfixion pin; the apparatus is then securely anchored into these casts. The author did not advocate its use as a routine procedure, but advocated the use of the apparatus in numerous conditions. These conditions include:

1. Fractures or dislocations of the pelvis or sacro-iliac joint;

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2. Central dislocations of the hip;
3. Fractures of the femur in the trochanteric region or in the shaft, but not supracondylar fractures;
4. Tibial fractures proximal to the malleoli;
5. Osteotomies of the femur, particularly in the subtrochanteric and intertrochanteric regions;
6. For the correction of flexion and adduction contractures of the hip;
7. In congenital and other dislocations of the hip;
8. A reversal of the apparatus for the correction of abduction contractures of the hip.

The advantages of the apparatus were given as: (1) minimal supervision as compared to the weight-and-pulley traction apparatus; (2) simplified nursing care; (3) mobility of the patient and the ease with which the patient can be placed in a wheel chair or on a stretcher; (4) the constancy of properly directed traction in maintaining alignment; and (5) shorter hospitalization and better adaptability to home care.

Disadvantages described were: (1) immobilization of the well extremity with its hazard to the knee and hip; (2) possibility of a pin-track infection, particularly in the well leg; (3) trochanteric bursitis on the well side as a result of the constant stretch; (4) limited amount of traction which can be employed; and (5) the risk of dislocating the well hip.

Dr. Roger Anderson[19], in discussing the paper, said that sliding and rotation of the pin can be avoided by using a small slotted lug on each end of the pin and incorporating it into the cast. He also recommended that the plaster-of-Paris over the patella be removed so that the patella could be mobilized.

It was also recommended that the posterior aspect of the foot and heel portions of the cast be re-enforced, so that the dorsum of the foot and ankle portion of the cast could be removed in order that motion in the foot and ankle could be started. Traction should not be applied too soon, because of the danger of distorting the cast. In the comminuted type of intertrochanteric fracture it was recommended that the traction apparatus be applied the day before the operation in order to facilitate pinning of the fracture.

Plea for the Standardization of Joint Measurements. Dr. Packard Thurber, Sr.[37] discussed the organization of the Industrial Accident Commission and emphasized the importance of accurate joint measurements and a standardization of joint measurements in the preparation of industrial accident reports. In 1948, Dr. Thurber and others were requested by the Commission to standardize joint measurements in industrial accident cases. The system of measurement developed as the result of this request was presented. This report was published by the Oxford University Press in 1950 under the title of *Evaluation of Industrial Disability*. This system has been adopted by the California Medical Association and the California Industrial Accident Commission.

The importance of properly recording hand and finger movements was emphasized and a hand block stamp was shown which could be used to shorten the recording process. One further point emphasized is the importance of considering the normal for a given individual as the uninvolved side (where there is an uninvolved extremity or joint on the opposite side to compare). Joint measurements are recorded in fractions, the range of movement of the injured joint being placed over the range of the uninjured.

The Use of a Dynamometer with Adjustable Handle Spacings. Dr. Charles O. Bechtol[20] has found that a dynamometer with adjustable handle spacings has definite advantages. The instrument is a modification of the cable tensiometer used in the aircraft industry. There are five different spacings of the handles, varying from one inch to three inches with increments of one-half inch. During compression, the handles move not more than one-fourth inch. It was recommended that the grip be tested at each of the five handle spacings where hand function permits, alternating between the right and the left hand. The normal male grip varies from 50 to 120 pounds, and the female from 30 to 70 pounds.

Factors influencing the grip were listed:

1. *The size of the object:* It was noted that the grasp usually varied about 30 per cent. less when the hand was grasping the handles at the one-inch and the three-inch spacings.
2. *Result of exercises:* Exercise usually increased the force of the grasp.
3. *Handedness:* The "major hand" was found to be as much as 30 per cent. stronger than the "minor hand".
4. *Variation during the day:* As much as 30 per cent. variation was noted at different times of the day, the grip being lower in the morning and reaching its maximum between 4:00 and 8:00 in the evening.
5. *Variation from day to day:* Approximately 10 per cent. variation was noted from day to day.
6. *The effect of pain:* Extreme variability was noted.

In testing the deformed hand, it was found advantageous to adjust the handles until the maximum force could be applied. This was particularly true in such conditions as Dupuytren's contractures.

When malingering was suspected, the test was repeated several times without the patient being permitted to see the result of the test. The normal variation of identical tests is approximately 10 per cent. whereas in malingerers it was not uncommon to note as much as 100 per cent. variation.

In the discussion Dr. Packard Thurber, Sr.[37] emphasized the importance of the grip in evaluating

[20] Seventh Street Building, Los Angeles, California.

and rating industrial injuries of the hands. He pointed out that the weakness of grip alone can run to a disability rating as high as 60 per cent., which in California means approximately $7,000.00. Dr. Thurber expressed the belief that Dr. Bechtol's adjustable-handled dynamometer could solve one of our greatest problems in evaluating industrial injuries.

Some Uses of Fascia Lata in Orthopaedic Surgery. Dr. J. Irving Tuell [38], who uses fascia lata as a suture material and as a tendon or ligament substitute, presented case studies illustrating these uses and emphasized that his results have been decidedly superior to his results achieved by other methods. Emphasis was placed on: (1) the need for gentleness in handling the fascia, since necrosis occurs at sites where the fascia is clamped; (2) the high tensile strength of fascia; and (3) the survival of fascia when transplanted and its adherence to host tissues within a few days.

Case studies illustrating the utilization of fascia lata in a variety of orthopaedic problems included the following:

1. *Fascia lata used as a tendon substitute in cases of total radial-nerve paralysis.* In one of the cases there was a flaccid triceps paralysis; in its treatment the posterior half of the deltoid muscle insertion was mobilized and a fascia lata graft, in the form of a tube, was extended between the mobilized muscle and the triceps aponeurosis just proximal to the olecranon. At each end the fascia lata tube was flattened and woven into the deltoid muscle at the proximal end and into the triceps aponeurosis distally. An abduction splint was used for five weeks. The end result was excellent.

2. *For rupture of the Achilles tendon.* Because of the frayed-out character of the tendon at the site of rupture, the fascia lata was found to be more physiological and more effective for the repair than other materials. Two fascia lata strips, one-half inch by eight inches, were used as mattress sutures; a cast was employed for only sixteen days; rehabilitation was rapid.

3. *Coracoclavicular slings to elevate a sagging scapula.* Several cases were described in which a fascia lata sling was placed between the clavicle and the coracoid process, elevating the scapula. A tube stripper was used to remove a strip of fascia lata, ten inches long and three-fourths of an inch wide. All immobilization was discontinued at the end of three weeks. Results were excellent.

4. *Repair after partial or total patellectomy.* Two or three fascia lata strips were extended between the quadriceps aponeurosis and the patellar tendon, and the fascia lata strips were woven and imbricated at each end. Immobilization of only three weeks was necessary. When the proximal pole of the patella was preserved, the proximal ends of the fascia lata strips were anchored into two vertical drill holes in the patella; in such cases rehabilitation was more rapid and more complete.

Dr. C. L. Lowman [39] in discussing Dr. Tuell's paper stated that he believes fascia lata deserves a wider application in orthopaedic surgery than it now enjoys.

He emphasized the importance of tension stresses in causing hypertrophy of fascial straps. It was pointed out that shearing stresses damage fascial straps and may cause areas of necrosis leading to rupture. It is Dr. Lowman's belief that the creation of a tube by the fascia lata transplant is unnecessary, the flat transplant being more effective.

A Splint for Use in Congenital Dislocation of the Hip or Dysplasia of the Hip. Dr. Frederic Ilfeld [40] in his presentation of an abduction splint for the treatment of congenital dislocation of the hip, emphasized the importance of early diagnosis and the advantages of a simple, inexpensive method of treatment. For use in infancy and early childhood, the author described a splint which has two thigh bands connected with an adjustable cross bar by a universal joint, locked in place with a hexagonal wrench which the surgeon retains. The thigh bands, covered with washable cuffs, are connected with the cross bar by a right-angle joint which has stops to allow motion through 90 degrees in order that the patient may sit or lie in comfort. Such a splint permits the perineum to be free for diaper hygiene, allows motion of hips and knees, and is readily adjustable to changes in adduction spasm and to accommodate growth. Its chief disadvantage is its failure to control rotation of the hip. If such control is required, a hip spica cast is advised.

Dr. Ilfeld reported the satisfactory use of this splint in twenty-eight patients of whom seven had had no other treatment; fourteen had first undergone closed reduction and plaster immobilization for seven to thirteen weeks; one had had a Colonna operation; and six showed evidence of dysplasia of the acetabulum. In only one patient had the hip redislocated while in the splint; this patient required a second reduction and was immobilized in a cast for three months. Other orthopaedic surgeons have used this splint in fifteen instances with satisfactory results. It is important to continue abduction exercises and to use the splint at night for one year or longer, until the acetabular index approaches normal.

In discussing Dr. Ilfeld's paper, Dr. Richard S. Dodge [41] spoke of the necessity for abduction treatment in the early stages of dislocated hip. The mechanical advantages of the splint are recognized. The most im-

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portant thing, however, is early diagnosis. The earlier the diagnosis is made, the better the end result achieved. To use this splint most efficaciously, the diagnosis must be made under one year of age.

In addition to the clinical methods for making diagnosis, it would be well to consider what type of people have congenital dislocations of the hip. It is prevalent in Northern Italy and Southern Austria. In Hawaii, a comparatively large series of cases shows that there is some racial prevalence in congenital dislocation of the hip. In a series of 118 patients the racial background was Japanese in eighty-nine, Hawaiian and part-Hawaiian in practically none, Portuguese and Filipino and others in a very small percentage. The percentage between sexes was 84 per cent. male and 16 per cent. female. Poliomyelitis and congenital club-foot were also prevalent in proportion to various races.

Some research into the prevalence of congenital deformities as related to where the people live, what they do, and what their race is would be worth while.

Conservative Approach in Treatment of Fracture of the Os Calcis. Dr. Leonard Barnard [38] and Dr. John K. Odegard [42], following a discussion of the methods used and the difficulties encountered in the treatment of fractures of the os calcis, proposed a conservative approach. By this method a cast is at once applied from toes to below the knee in the equinus position with a large pad of sponge rubber about the heel and a walking rubber heel fixed to the cast far forward at the level of the metatarsal heads. The patient is encouraged to bear as much weight as possible. The cast is removed after six weeks and the heel of the shoe is raised one and one-half inches; it is gradually lowered during the succeeding six to eight weeks. If marked swelling has already occurred, a preliminary period of elevation is required before the application of the cast.

Thirteen private patients have been so treated, of whom nine have been followed for more than one year. The average period of disability was twelve weeks and all but one returned to his regular occupation. The authors feel that with such a method of treatment subtalar arthrodesis will rarely be required.

Dr. Christopher Mason [43], in discussing this paper, agreed with Dr. Barnard that plantar flexion of the foot is highly desirable. He also feels that pronation or valgus of the heel is desirable in the more severe squash fractures when the medial sustentaculum tali portion has been split off and pushed down, in order that it may be pulled back up on the side of the heel. If this is done, then, when the patient begins to walk, the sustentaculum will again be able to support the arch at a normal level when the heel rotates back to a normal position; and, at the same time, any remaining bone which might impinge beneath the lateral malleolus will tend to rotate away from this point. This could hardly become re-attached in less than two months for full weight-bearing.

The contention of Cotton that we must, so far as possible, clean the bone from beneath the lateral malleolus, advocated as early as 1903, is still valid, and the incorporation of felt rolls as advocated by Hermann is often quite useful in maintaining this. The salient angle appears not to be too important clinically.

The weakening of the gastrocnemius spoken of by Dr. Barnard is caused by inability to use the muscle because of lateral submalleolar pain. Putting the foot in plantar flexion and eversion and at the same time pushing the bone back and restoring the submalleolar groove will help to avoid this pain.

New Technique for Repair of Torn Collateral Ligaments of the Knee. Dr. John R. Black [44] described a modification of the Mauck operation for the repair of the collateral ligaments of the knee. This technique consists in the upward transplantation of the femoral insertion rather than the downward shifting of the tibial attachment of the tibial collateral ligament. In a similar fashion, a relaxed fibular collateral ligament may be tightened by the upward transplantation of a bone flap including its femoral insertion. A cast is worn for seven weeks postoperatively, and after that a brace. Two cases were reported in which this operation had been used with satisfactory results.

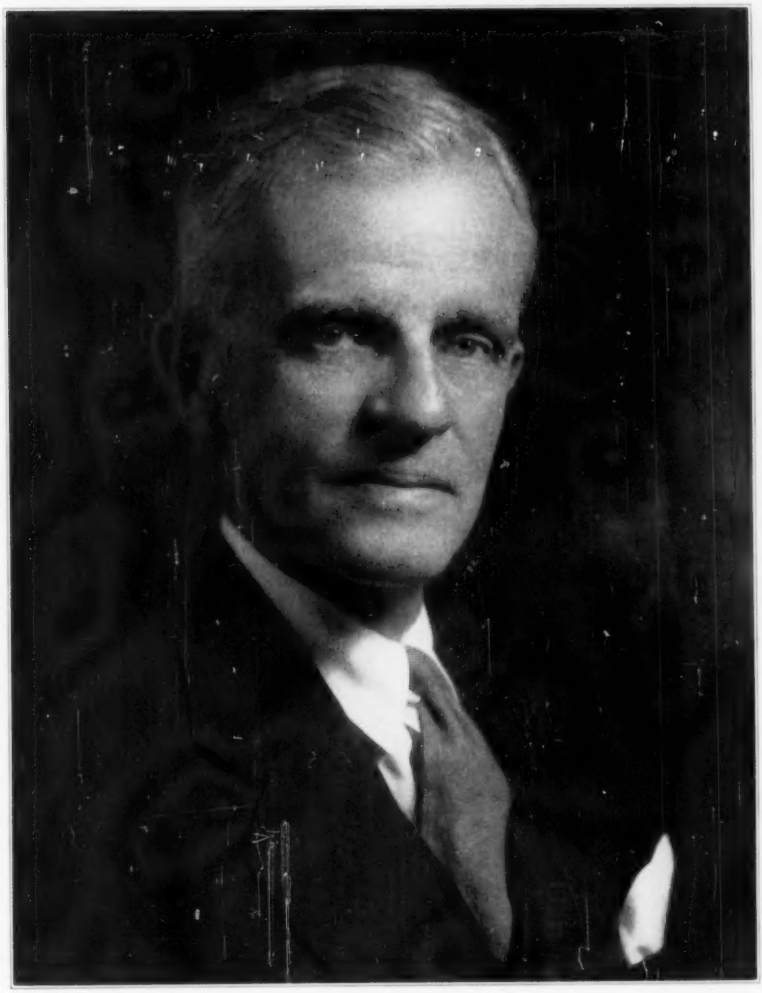
Discussing Dr. Black's paper, Dr. Harold Crowe [45] pointed out the difficulties of accomplishing the ideal in knee-joint repairs, even by masters in orthopaedics. He stressed the importance of the "cure" being helped by the patient building up his quadriceps power.

Dr. Don O'Donoghue [46] stressed the importance of seeing ligamentous knee injuries immediately if an accurate diagnosis is to be made. In his opinion, Dr. Black, by this technique, is not restoring the ligament but substituting a fascia lata strip which under intermittent pull and relaxation will hypertrophy and become tendinous in character. The proof of its efficiency can only be determined after many years of careful follow-up of the patients operated upon by this method.

Osteotomy of the Cervicothoracic Spine. Dr. Christopher A. Mason [42] and Dr. Lewis Cozen [47] reported a case in which an osteotomy was done through the first thoracic vertebra to correct the extreme flexion

(*Continued on page 798*)

[42] 2039 Summit Street, Oakland, California.
[43] 2865 Wilshire Boulevard, Los Angeles, California.
[44] 1930 Wilshire Boulevard, Los Angeles 5, California.
[45] 635 South Westlake Avenue, Los Angeles, California.
[46] Northwest Tenth and Lee Streets, Oklahoma City 2, Oklahoma.
[47] 2007 Wilshire Boulevard, Los Angeles, California.



WILLIAM WARD PLUMMER

(1877–1953)

Modern orthopaedic surgery lost one of its strongest proponents when William Ward Plummer died, February 16, 1953. His seventy-five years had been well spent, but he paid no heed to them; he died a young man, regardless of his time of life. He was young in spirit, young in venture, and young in enthusiasm. He died disgusted with his physical infirmities, because they interfered with his mental activities.

Dr. Plummer's activities in the orthopaedic field had spanned the era of almost non-surgical conservatism to that of the aggressive, brilliant accomplishments of the modern orthopaedic surgeon. His ability was recognized by his membership in the leading orthopaedic societies in the country and in his executive positions in them. He was a student and a teacher, occupying the Professorship of Orthopaedic Surgery in his Alma Mater, The University of Buffalo, for nearly twenty-five years. His counsel was widely sought and his opinion was highly regarded. Numbered among his friends both in his personal and professional life was a noticeable number of young men. They constantly sought and accepted his counsel and guidance. None could be more appreciative of the strength or more understanding of the weakness in men than he. Always kind, understanding, and helpful, he was at all times a gentleman.

He served in World War I and during World War II he was called as a civilian consultant. There was

no activity in his career which he enjoyed as much as this assignment. He continued in this capacity with great sacrifice to his practice and to his health.

Dr. Plummer's contributions to orthopaedic surgery were largely in his teaching and his care of patients. He was not a prolific writer, but the value of his writings was in their merit rather than volume. He is missed by a host of friends.

"Say not with grief he is no more," but rather say with gratitude, "he was".

Proceedings

(*Continued from page 796*)

deformity of an ankylosed cervical spine in a man, forty-two years of age. Skull traction was used for two weeks postoperatively, followed by a plaster jacket from head to pelvis for four weeks, succeeded by a cervical brace with head band, which was still being worn when the patient was last observed one year after the operation. The only complication was a transient laryngeal palsy.

In his discussion, Dr. Paul E. McMaster[48] stated that this case probably represents the first cervicothoracic osteotomy to be performed in the United States; lumbar osteotomies have been performed a number of times. He believes the lack of neurological complications following surgery in this case was due to the wide area of the laminectomy performed prior to the osteotomy.

An Operation to Increase the Relative Length of Short above-the-Elbow Stumps. Dr. Robert Mazet, Jr.[24] In order to lengthen a short above-the-elbow amputation stump sufficiently to permit the fitting of a prosthesis, Dr. Mazet had incised the distal half of the tendon of the pectoralis major near its insertion and had folded this half over its proximal half. In two instances he gained one inch and one and a quarter inches respectively in length of stump and thus made possible the use of the conventional prosthesis.

Tendon Transplantation in the Forearm and Hand. Dr. Walter C. Graham[25] gave a comprehensive review of the various possibilities of mobilizing or stabilizing the digits and the wrist so that the hand can be made more useful following disease or injury.

In considering the procedures to be carried out, the surgeon must determine the exact extent and degree of involvement of the muscles and joints and must evaluate the available muscles for transplantation. The arthrodesis of a joint such as the wrist may enhance the possibilities of reconstruction by rendering available the muscles which control this joint. The second method of increasing the usefulness of available muscles is that of tenodesing the tendons of the paralyzed muscle to bone structures or intermuscular septa. An example is the fixation of the flexors of the fingers proximal to the wrist into the radius so that the normal extension of the wrist closes the fingers automatically.

The various types of tendon transplantation for improving the function of the fingers and thumb were discussed at length. A tabulation was presented of the muscles which could best be employed in substitution for the commonly paralyzed or injured muscles.

[48] 9730 Wilshire Boulevard, Los Angeles, California.

LETTER TO THE EDITOR

. . . .

May I add that I have read with great interest the excellent article on the National Health Service by Dr. Stewart (Vol. 35-A, pp. 245-251, January 1953). A few comments occurred to me as I studied it, for I am a family doctor in the Service. I do not know of any regulation forbidding me to treat certain cases, and requiring me to send them to hospital (p. 247). I am required to do what seems to me best for each patient. I have sometimes to advise specialist care in hospital of course. If I believe this is not in the best interest of the patient however, I must advise against it, and can under the Service obtain specialist, laboratory, and/or radiological help if need be, in his home.

I do not share Dr. Brown's views on Yorkshire. Perhaps this is because I've lived here all my life . . . or nearly all, for I spent two years in Cleveland, Ohio, for which I remain very grateful to the Rockefeller Foundation.

Dr. George Johnson
57 East Parade
Harrogate, England

30th April 1953

News Notes

The deadline for the receipt of applications for the 1954 Part II examinations of **The American Board of Orthopaedic Surgery** is August 15, 1953. Applications should be sent to the Secretary, Dr. Harold A. Sofield, 122 S. Michigan Avenue, Chicago, Illinois.

Dr. Fremont A. Chandler delivered the **Sir Robert Jones Lecture** at the Hospital for Joint Diseases, New York City, on Wednesday, April 29. His subject was "Muscular Torticollis".

The **Alabama Orthopaedic Society** was organized on April 17, 1952, and the following officers were elected:

President: Dr. Paul Shannon, Birmingham, Alabama.
Vice-President: Dr. T. J. Bender, Birmingham, Alabama.
Secretary-Treasurer: Dr. D. G. Vesely, Birmingham, Alabama.

The First Annual Meeting was held at the Thomas-Jefferson Hotel, April 15, 1953, in conjunction with the annual meeting of the Medical Association of Alabama.

A prize of $1,000, donated by the **Kappa Delta Sorority,** may be awarded annually by **The American Academy of Orthopaedic Surgeons** for the best research related to orthopaedic surgery and performed by an American citizen in the United States.

The selection will be made from publications after January 1, 1951, or research presented to the Committee on Scientific Investigation of The American Academy of Orthopaedic Surgeons before November 1, 1953.

Researchers interested in competing for the award are requested to secure further information from Dr. John J. Fahey, 1791 West Howard Street, Chicago 26, Illinois, Chairman of the Committee on Scientific Investigation of The American Academy of Orthopaedic Surgeons.

TRANSPLANTATION BULLETIN

An effort is being made to increase the exchange of information between clinical and laboratory investigators working in the field of tissue transplantation. The United States Public Health Service sponsored a conference in October 1952 at Harriman, New York, where workers in plastic surgery, cancer, zoology, and other fields discussed common problems in tissue transplantation. In March 1953, the Ciba Foundation sponsored another conference in London on the "Preservation of Normal Tissues for Transplantation". At both conferences it was felt that some means should exist for continuing to exchange information on an informal basis among clinical and laboratory investigators interested in the field, and so it is proposed to issue quarterly the *Transplantation Bulletin* to serve the following functions:

1. It will maintain, and publish at least once yearly, a Transplantation Registry which will list all practising physicians and research workers, both in the United States and abroad, interested in transplantation problems. The Registry will cover the fields of plastic surgery, endocrinology, cancer, genetics, immunology, and experimental morphology.

2. The Bulletin will provide a medium for a rapid and informal exchange of information on problems and progress in the clinics and laboratories both here and abroad. It is emphasized that the Bulletin will not publish formal papers. However, brief comments on unreported data will be welcomed.

3. It will, through a staff of Corresponding Editors, attempt to keep all members of the Transplantation Registry informed of forthcoming meetings of the professional societies, at which there will be presentations dealing with any aspects of transplantation. It will also try, through its Corresponding Editors, to have the subjects covered in a coordinated fashion at the meetings.

4. It will maintain a bibliography in the fields covered.

The *Transplantation Bulletin* invites anyone in the field of medicine or biology who is interested in tissue transplantation to submit his name and field of interest to E. J. Eichwald, M.D., University of Utah College of Medicine, Salt Lake City, Utah. A subscription fee of $3.00, to cover expenses of printing the Bulletin and maintenance of the Registry and bibliography, will be payable after the first issue of the Bulletin has appeared. The first issue is expected to appear in August 1953.

Book Reviews

HUMAN LOCOMOTION AND BODY FORM, A Study of Gravity and Man. Dudley J. Morton, M.D., with collaboration of Dudley Dean Fuller. Baltimore, The Williams and Wilkins Co., 1952. $5.00.

The authors' avowed purpose is to present the thesis that gravity has been a major designing agent in the physical structure of man, particularly of the foot. The book is divided into two parts. The first presents the underlying principles of adaptation; the second, an analysis of the walking stride.

In the former the author traces the evolution of man with particular reference to the development of his locomotor apparatus. In his discussion of genetics he produces a rather convincing argument for the inheritance of acquired characteristics. He then reviews the mechanical analysis of the human foot as a weight-bearing organ which he has published previously, and concludes this part by reaffirming his concept of the etiology of many of the common mechanical disorders of the foot. He attributes these to shortness or hypermobility of the first metatarsal. He also suggests that posteriorly located sesamoid bones, especially in women, may be an etiological factor as well. In this connection he offers a rebuttal to the conclusions concerning these abnormalities which were presented by R. I. Harris and Thomas Beath in the Canadian Army Foot Survey.

The second part commences with a detailed, mechanical analysis of the walking stride written with the assistance of Prof. Fuller of the Department of Mechanical Engineering of Columbia University. Evidence is then produced from metabolic studies that the force of gravity contributes a substantial amount of the energy required for walking on the level. This is maximum at a certain walking speed, diminishing as this speed is increased or reduced. Similarly, muscle physiology is considered as it is related to locomotion. The elastic property of muscle is emphasized, showing that the presence of this in the gastrocnemius soleus group serves to minimize the energy requirement during locomotion. In the final chapter the evolution of man is reconsidered, man's development being traced from arboreal anthropoid stock. The author points out that man alone is an erect terrestrial biped. The semi-erect position of the anthropoid apes is a reversion to quadrupedism and not a phase in man's evolution. With the upper extremities freed from serious gravitational stresses, these structures became adapted to prehensile function and, following this, cranial enlargement occurred as the result of the development of the central nervous system. This latter development occurred only after our prehuman forbears had adopted bipedism and begun to use the upper extremities for purposes other than locomotion. It is thus that gravity has exerted a profound influence on the development of man as a whole, as well as on the form and function of the feet and lower extremities.

The book, presenting as it does a functional rather than the usual morphological analysis, and correlating this with comparative vertebrate anatomy, is most interesting and well worth reading. The analysis of gait is difficult reading for one not mathematically inclined, but this part of the presentation is kept at a minimum. The book can be recommended highly.

MEDICAL DISORDERS OF THE LOCOMOTOR SYSTEM INCLUDING THE RHEUMATIC DISEASES. Ed. 2. Ernest Fletcher, M.A., M.D. (Cantab.), M.R.C.P. Baltimore, The Williams and Wilkins Co., 1951. $11.00.

Under this title the author has included medical disorders of bones, joints, and muscles, as well as of the peripheral nerves and blood vessels. A large part of the text is devoted to the rheumatic diseases, in many of which pathological alterations are generally distributed rather than limited to the locomotor system. To this second edition, which is nearly half again as lengthy as the first, chapters have been added on pain, the anatomy and physiology of bone, the neuropathies, the collagen diseases, psychiatric aspects of locomotor disorders, and cortisone and ACTH. Many of the remaining chapters show evidence of revision, with the inclusion of additional material. In spite of the increased length of the book, a number of subjects, chiefly among the rheumatic diseases, are not adequately covered. Under therapy, outmoded or dubious methods are still mentioned without the critical appraisal which would be of assistance to the inexperienced reader, and the date of publication unfortunately precluded an up-to-date consideration of the uses of cortisone and ACTH. Although the volume contains a wealth of helpful information, it can be recommended only as a supplement to more definitive texts.

THE STORY OF THE ADAPTATION SYNDROME. Hans Selye, M.D., Ph.D. (Prague), D.Sc.(McGill), F.R.C.S. (Canada). Montreal, Acta, Inc., 1952.

Prof. Selye, in this informal book, presents his concept of the adaptation syndrome in a fashion which should please the reader whose medical interests are general rather than special or technical. The origin of the syndrome makes interesting reading for anyone who likes to know how things came to be; those struggling with an obstinate research problem will be interested to know that the discovery of the syndrome can be traced back to an accidental observation made in the course of experiments inspired by a faulty theory, as the author admits with embarrassment.

The author's much larger and previously published work, *Stress*, contained source material of value to the research worker; this smaller book will appeal to those who wish a comprehensive summary of this new concept of disease, and medical students should find it very informative. This newer and smaller book presents some changes in terminology: in *Stress** Dr. Selye used the terms mineralo-corticoid (M-C) and gluco-corticoid (G-C), terms based on biochemical effects. As studies of these two groups progressed, it became clear that some gluco-corticoids (for example, cortisone) had sodium-retaining properties in certain dosages and, therefore, shared in the chemical effects of the mineralo-corticoids such as desoxycorticosterone. The author has now, therefore, adopted terminology which stresses the physiological effects rather than the chemical, and instead of the term "gluco-corticoid" he uses "antiphlogistic corticoid" (A-C) and for "mineralo-corticoid" he uses "prophlogistic corticoid" (P-C). Certainly the demarcation between an agent inhibiting inflammatory response and one facilitating or exaggerating such a response would seem to be sharp, and the change should both clarify our thinking and be more in keeping with the facts.

The illustrations are simple and clear, the style is that of the informal lecture. The book will probably prove to be the most readable and most popular of all the author's published works.

Orthopädische Schuhe und Stützeinlagen zur Behandlung von Fehlern der Füsse und Beine. Dr. med. Carl R. H. Rabl. Stuttgart, Ferdinand Enke Verlag, 1951. DM 16.

This book on orthopaedic shoes and arch supports was written not only for the benefit of physicians interested in orthopaedic anomalies and diseases of the foot, but also for orthopaedic shoemakers. The first and second chapters deal essentially with the technique of making the orthopaedic shoe, as well as with the various types of shoes made for normal and abnormal feet. The third chapter deals with the various abnormal positions of the foot, as well as with their correction by proper plates or shoes. The fourth chapter discusses anomalies of the heel and their corrections. The fifth and sixth chapters discuss the various diseases of the metatarsal arch and the toes. The seventh chapter discusses the correction of pes equinus. The chapters from the eighth to the thirteenth deal with various diseases of the legs which lead to abnormalities in the position or function of the feet, as well as their correction by proper shoeing or the fitting of orthopaedic appliances. In a final chapter, the use of shoes for various types of amputation of the foot is discussed.

In an appendix, the author outlines special rules for the need of orthopaedic shoes, so that they will not be unnecessarily ordered. He includes a simple outline of anatomical terms for use by the orthopaedic shoemaker.

The book is written in highly technical terms, but it contains valuable information for both the orthopaedic surgeon and the manufacturer of special shoes. It is accompanied by simple and well executed drawings. It should be of value to those who can read German easily.

Orthopädische Technik. Bandagen und Apparate, ihre Anzeige und ihr Bau. Prof. Dr. Georg Hohmann. Stuttgart, Ferdinand Enke Verlag, 1951. DM 23.

This is the third edition of a short book on orthopaedic technique which was originally published in 1941. The author discusses in simple and easily understood terms the various technical appliances used by orthopaedic patients. The greater part of the book is devoted to the postoperative use of appliances in Germany. These are essentially simple and inexpensive. There is a chapter dealing with artificial limbs. This is somewhat inadequate, because of lack of experience with the newer light-weight materials. The suction-socket prosthesis has not been thoroughly considered. Many of the devices recommended in this book have been improved upon in this country, but the author is correct in describing the methods which are available in Germany.

It is of interest that the book does not contain any reference to the conservative or postoperative treatment of the herniated intervertebral disc. This book is not recommended for universal use because of these omissions, but it would be of great interest to those who are interested in the technical appliances used by an excellent orthopaedic surgeon.

Architectural Principles in Arthrodesis. Ed. 2. H. A. Brittain, O.B.E., M.A., M.Ch., F.R.C.S. Edinburgh, E. & S. Livingstone, 42 shillings; Baltimore, The Williams & Wilkins Co., 1952. $8.00.

The second edition of this well known little book has been almost completely rewritten, and it has been enlarged from 126 to 193 text pages. The author, as a result of increasing experience, has modified some of the techniques previously described and he has added new chapters as well.

In the first edition, he reported that he had used his so-called V-arthrodesis of the hip, which employs a Smith-Petersen nail and graft, on only one patient. This technique is now described in a separate chapter and the results are given of forty-two operations on forty patients. There are also sections devoted to arthrodesis of the symphysis pubis and of the carpometacarpal joint of the thumb, as well as a chapter on the Naughton Dunn operation for stabilization of the foot.

The book is profusely illustrated in black and white and in color. There are also many reproductions of x-rays from illustrative cases.

* Reviewed in this *Journal*, Vol. 33-A, No. 3, p. 818, July 1951.

Although this edition is somewhat marred by typographical errors, including the repetition of one entire sentence on page 188, it is recommended highly to orthopaedic surgeons. In a clear and concise fashion, it gives both the theoretical and technical considerations of this type of surgery, based on the author's wide experience.

CALLANDER'S SURGICAL ANATOMY. Ed. 3. Barry J. Anson, M.A., Ph.D. (Med.Sc.), and Walter G. Maddock, M.S., M.D., F.A.C.S. Philadelphia, W. B. Saunders Co., 1952. $14.00.

The third edition of *Callander's Surgical Anatomy* was revised on the principle, in the words of its editors, that "the original pattern of presentation should be retained, and that fundamental features, not detailed surgical technique, should be stressed, since technical procedure may quickly become obsolescent, whereas structure remains unchanged".

Working apparently without indication of the late Dr. Callander's plans for revision, the authors have made a careful selection of illustrations used in the previous editions and added many new illustrations. The order of chapters is the usual one of description by systems. As in previous editions, the book confines itself to a general discussion of each of the various skeletal disorders. However, brief paragraphs on diagnostic signs and symptoms in the more common orthopaedic lesions are included, and there is an excellent balance between clinical material and anatomical considerations.

For the surgical intern or resident, as well as for the general practitioner, *Callander's Surgical Anatomy* has always been an indispensable work. This edition, with its thorough revision of chapters by the various contributing specialists, will again be a needed addition to their libraries.

RARE MANIFESTATIONS OF METABOLIC BONE DISEASE. Their Practical Importance. I. Snapper, M.D., Ph.D. Springfield, Illinois, Charles C. Thomas, 1952. $3.00.

Rare Manifestations of Metabolic Bone Disease, published in The American Lecture Series, is a printing of the Twenty-ninth Annual Beaumont Lecture delivered before the Wayne County Medical Society on February 6, 1950.

Dr. Snapper begins his lecture with an admirable and concise discussion of osteogenesis, calcium metabolism, and disturbances of metabolism and diseases of the skeleton. In the latter section of the introduction he discusses briefly the different diseases of the skeleton closely connected with changes of metabolism and says, in summary, "It is emphasized that clinical syndromes are encountered in which the bone lesions, even if present, remain in the background, whereas the metabolic changes are in the foreground. These relatively rare manifestations of metabolic bone disease are of great practical importance."

The body of the lecture, in three sections, is devoted to illustrating the practical diagnostic and therapeutic aspects of metabolic disturbances of the skeleton. The first section is devoted to hyperparathyroidism, the discussion of which begins with certain historical and clinical remarks and continues with case histories of the disorder and observations on the course of the disease and its treatment, gained from the histories. The second part, dealing with multiple myeloma, is presented similarly in two sections: the third section deals with hypercalcaemia, hypophosphataemia, and hypercalciuria in diseases other than hyperparathyroidism. Here are discussed such diseases as von Recklinghausen's disease, Paget's disease, osteomalacia and rickets, and lipoid granuloma of bones.

The book—well printed, excellently although not abundantly illustrated, and bound in durable leatherette—coming from such a master of the subject, will be a most welcome addition to the libraries of men who are interested in diseases and disorders of the skeletal system.

DER MUSKULÄRE SCHIEFHALS BEIM NEUGEBORENEN. Helmut Kastendieck. Zwanglose Abhandlungen auf dem Gebiete der Frauenheilkunde, Band 12. Leipzig, Georg Thieme, 1952. DM 7.

Written from the point of view of obstetrics and forming part of a series of publications in the field of gynecology, this monograph will nevertheless be of interest to the orthopaedic surgeon. The emphasis is chiefly on etiology, and an attempt is made to correlate the incidence of breech presentations with torticollis.

From a discussion of the pathogenesis of scoliosis capitis and faciei, which is explained entirely in terms of the position of the foetus, the author proceeds to analyze the etiology of torticollis (caput obstipum musculare). He sides with those who claim that hereditary factors play only an indirect part in the mechanism of this condition (that is, in so far as the tendency to breech deliveries may be inherited) and that the actual production of this condition is due entirely to intra-uterine factors.

The types of torticollis encountered at birth are divided into potential, incipient, and complete. The discussion of treatment is limited to non-operative therapy. A plea is made for postponing all operative treatment until the end of the first year, as the author believes that only a third of the cases of torticollis diagnosed at birth persist after a year. A padded splint is advised for cases of incipient torticollis.

The book is recommended as an addition to the ever-growing literature on congenital and neonatal deformities.

INJURY OF THE XIPHOID. Michael Burman and Samuel E. Sinberg. New York, Columbia University Press, 1952. $3.50.

The authors have presented from their own practice this study of between seventy-five and 100 cases of disease of the xiphoid.

From their research they find that a similar study has not been made since medieval times. Historical samplings are made of medical writings as related to symptoms supposedly related to abnormalities of the xiphoid or of its absence.

The epigastric syndrome of pain and tenderness over the xiphoid is discussed. It is pointed out that the xiphoid is normally slightly tender to palpation.

The numerous case reports presented represent the bulk of the monograph. The probable relationship of the patient's complaints and a disorder of the xiphoid is inferred in each case. Some patients have had relief of symptoms by supportive strapping, binding, local heat and rest, ethylchloride freezing, and local infiltration. Others have required local excision.

Direct injury to the xiphoid is covered with numerous case reports. The traumatic factor of the steering-wheel injury is illustrated.

The monograph is illustrated with x-rays, diagrammatic sketches, and photographs of pathological specimens.

A comparison with coccyx pain is made and possible psychogenic factors are briefly considered.

The authors point out the advisability of routinely suspecting and examining the xiphoid in epigastric disorders. They emphasize that open reduction or removal of the xiphoid is not routinely indicated, but rather is it a measure of last resort.

THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS INSTRUCTIONAL COURSE LECTURES. Vol. IX. Charles N. Pease, Editor, Ann Arbor, J. W. Edwards, 1952. $10.75.

The 1952 Volume of these annual lectures, edited by Dr. Charles N. Pease, maintains the format and general excellence of previous publications. It is somewhat longer than many of the earlier volumes and contains 442 text pages. Several subjects are considered in detail, from two to five lectures dealing with each. Included are lectures on spine fusion, cerebral palsy, the anatomy of joints, hand surgery, braces, engineering principles as applied to orthopaedic surgery, the shoulder, the ankle, and the foot. The contributors to these sections are all authorities on their subjects and the presentations attain a high degree of excellence throughout. Of particular merit are the sections on engineering principles and splints and braces.

There is a timely and excellent article by Dr. Walter P. Blount on "Proximal Osteotomies of the Femur" as well as papers of particular interest on "Contact Compression in Osteogenesis" by G. W. N. Eggers, on "Disability Evaluation" by Chester C. Schneider, on the "Orthopaedic Aspects of Myasthenia Gravis", and on the "History and Biography of Orthopaedic Surgery" by H. Winnett Orr.

This volume can be recommended highly, and it deserves a place in the library of all orthopaedic surgeons.

POST-GRADUATE LECTURES ON ORTHOPEDIC DIAGNOSIS AND INDICATIONS. Vol. IV. Arthur Steindler, M.D. Springfield, Illinois, Charles C. Thomas, 1952. $9.75.

This is the fourth and final volume in this series of outstanding orthopaedic lectures. Students of orthopaedic surgery are deep in Dr. Steindler's debt for making his lectures available to them. As mentioned in reviews of the previous three volumes, these lectures represent material which this master teacher has presented to his many students during a distinguished career as a lecturer, surgeon, and investigator.

This work is presented in two sections,—Section A on arthritis and diseases of muscles, bursae, tendons, and fascia; and Section B on deficiency and degenerative diseases of the locomotor system.

Section A deals comprehensively with rheumatoid arthritis and osteo-arthritis. As might be expected, the best lecture in this section is on the fundamentals of orthopaedic treatment. Also included in Section A are good discussions of gout, pyogenic arthritis, syphilis, Dupuytren's contracture, diseases of tendons and bursae, and the muscular dystrophies and atrophies.

In Section B, in the discussion of the avitaminoses, the vitamin-D-deficiency states are presented in considerable detail. Paget's disease and osteoporosis are described as are also localized and generalized fibrosing osteitis. The lipoid dystrophies are discussed in an important lecture as are the entities which have avascular necrosis as their basis. The final lecture presents a splendid description of the neuro-arthropathies.

In Volume IV, as in the other three volumes, the student is taught to diagnose and analyze the case at hand. He then possesses a knowledge which enables him to plan accurately a program of therapy. Only basic considerations of therapy are included in these volumes.

Students of orthopaedic surgery, young and old, will profit by having this fine series of lectures close at hand.

SOME PRINCIPLES OF HAND SURGERY. John J. Byrne, M.C. Boston, privately printed.

Some Principles of Hand Surgery is a twenty-one-page, paper-bound manual which covers in one or more sentences almost any condition or situation which can occur in a hand. It is obvious from its total length that

most of these conditions are described in great brevity although often with a useful reference. The technique is mentioned but hardly in sufficient detail to prove useful. Some ninety different conditions are covered in different paragraphs in eighteen pages and then there are two pages of references. With this amount of material packed into a small space, it seems surprising that an entire page should be devoted to the use of galvanic current, which must indeed play a relatively small part in the diseases and injuries of the hand. No alternatives to the specified therapies are mentioned and the general tone is arbitrary.

Perhaps the best use for such a manual would be as an outline to a series of lectures, given to students in the place of lecture notes. The reviewer feels that it represents the most complete outline of hand conditions and injuries which has ever been compiled in so small a space.

Surgical Practice of the Lahey Clinic. By Members of the Staff of Lahey Clinic, Boston. Philadelphia, W. B. Saunders Co., 1951. $15.00

In this volume the section of interest to readers of this *Journal* contains the following articles: The Treatment of Primary Malignant Bone Tumors of the Humerus, by G. Edmund Haggart; Cauda Equina Tumors as a Cause of the Low-Back Syndrome, by James W. Toumey, James L. Poppen, and Melvin T. Hurley; The Surgical Treatment of Fractures of the Lateral Tibial Condyle, by G. Edmund Haggart and Howard M. Clemmons; and The Management of Chronic Suppurative Osteomyelitis of the Femur, by G. Edmund Haggart and Melvin T. Hurley. The publication in one volume of the many excellent papers by members of the Staff of this Clinic will be appreciated by many.

Manual of Massage and Movements. Ed. 3. Edith M. Prosser, T.M.M.G. Philadelphia, J. B. Lippincott, 1951. $5.00.

The Third Edition of *Massage and Movements* reviews in brief a history of massage and exercise. It first classifies then demonstrates the forms of manipulations used in massage, giving the physiological effects upon the different systems of the various manipulations. Both the mechanical effects and the correct positions are demonstrated by "match" figures. These are used throughout the 353 pages.

The normal ranges of motion of the different joints are well described in a systematic manner showing the relationship of range in the various classifications.

Exercises for the joints are tabulated and are demonstrated. A few useful suggestions for special breathing exercises are included.

The various types of spinal deformities and the treatment for correction are described.

There is an appendix which includes some simple adjuncts to treatment with a few examples which should prove of practical value to the physiotherapist.

Included are sets of examination questions of the Chartered Society of Physiotherapists which include questions for the blind physiotherapist.

B for Medical Writing. A Useful Guide to Principles and Practice of Effective Scientific Writing and Illustration. Edwin P. Jordan, M.D., and Willard C. Shepard. Philadelphia, W. B. Saunders Company, 1952. $2.50.

Prepared for the author with little or no experience in medical writing, this book offers helpful suggestions for the beginner. Many of the points made are worthy of consideration. The emphasis on careful preparation and multiple revision of the manuscript will be commended by all editors.

Opinions will differ about some of the other recommendations made, such as the form of index to be used and the addition of a summary for the obvious purpose of letting the reader decide if he wishes to peruse the entire article. (Such a summary seems more than superfluous to the careful reader who arrives at the end of the article to find a summary telling him what he has just read!)

The section on illustrations will be of great help to those preparing their first illustrated papers. Some publishers would take exception to the advice given about furnishing prints, five by seven inches, of roentgenograms and the statement that more detail is retained when the reduction is made by the photographer than if made by the engraver. *The Journal* has found it necessary to refuse many such small prints of roentgenograms because so much detail has been lost, but has also found that excellent reproductions of bone lesions could be made from direct contact prints from these same roentgenograms. However, most of the information given about the different types of illustrations is valuable.

The chapter on "Statistics Employed in Medical Papers" contains many worth-while features as do the appendices.

ACKNOWLEDGMENTS

The Journal wishes to acknowledge receipt of the following publications which have been sent to the Editorial Department:

Accademia Medica. Bollettino ed Atti dell' Accademia Medica di Genova ed Archivo di Scienze Mediche (Genova), **58–59:** 1943–1944; **60–61:** 1944–1946; **62:** 1947.

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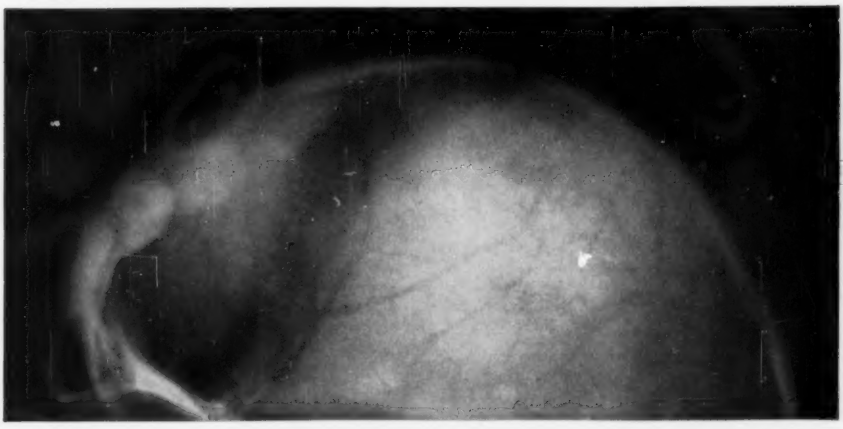

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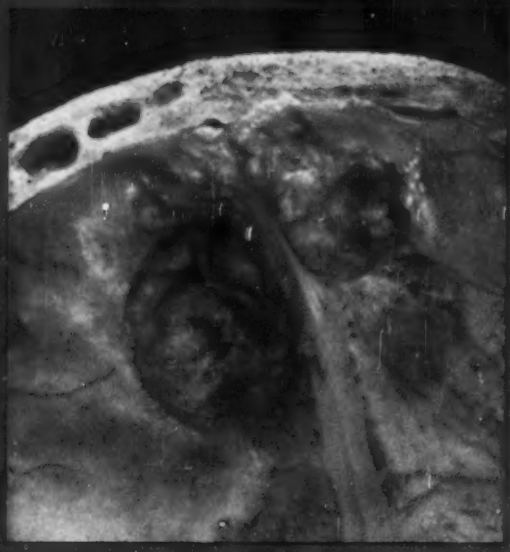

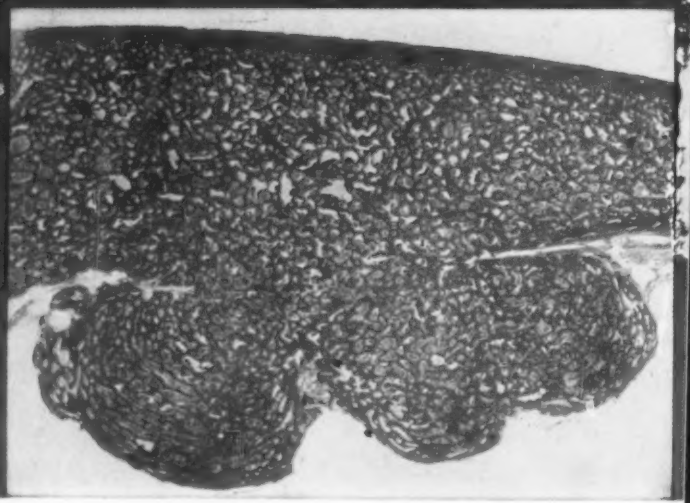

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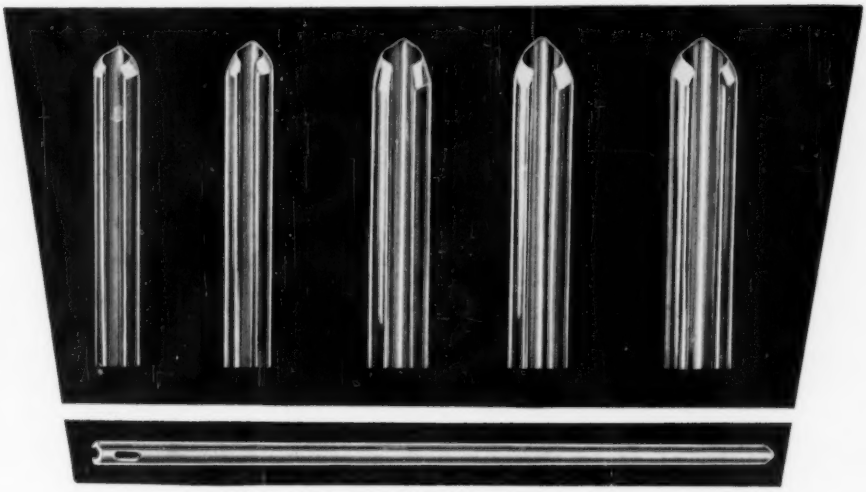

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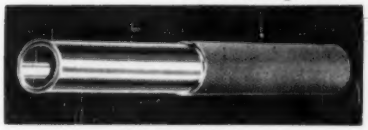

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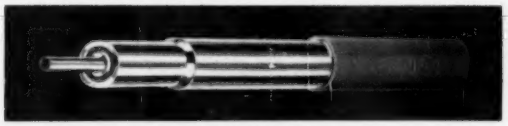

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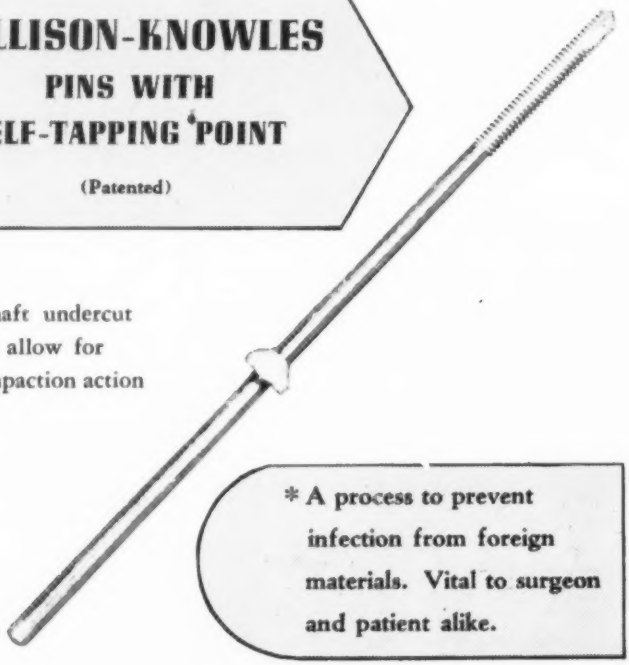

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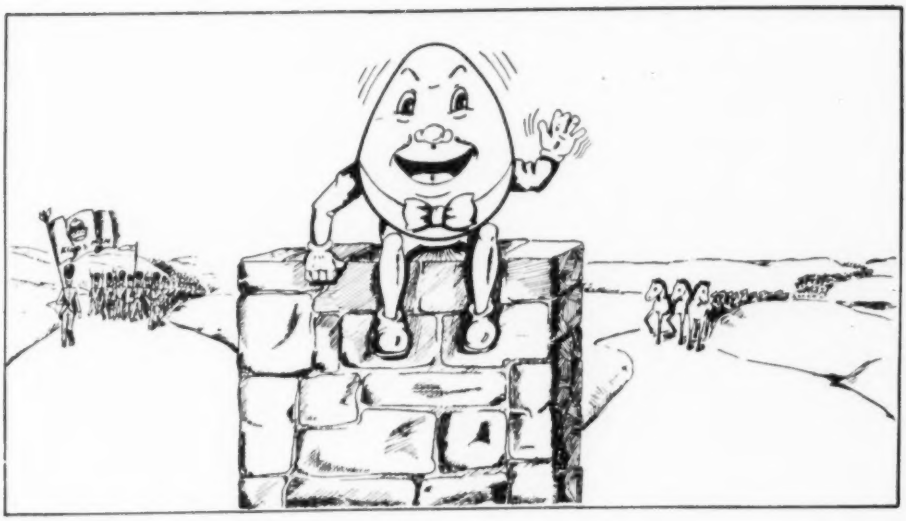

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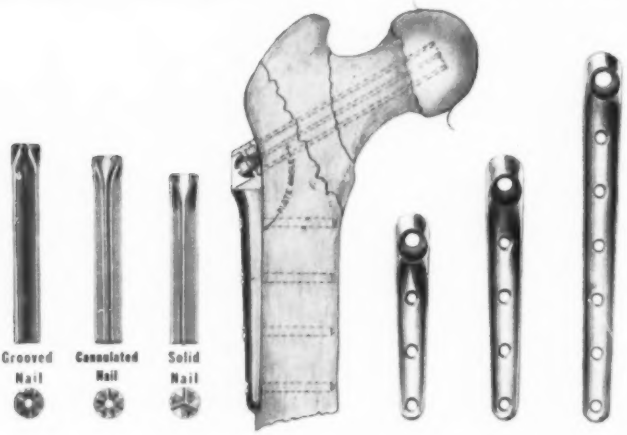

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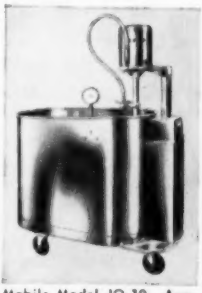

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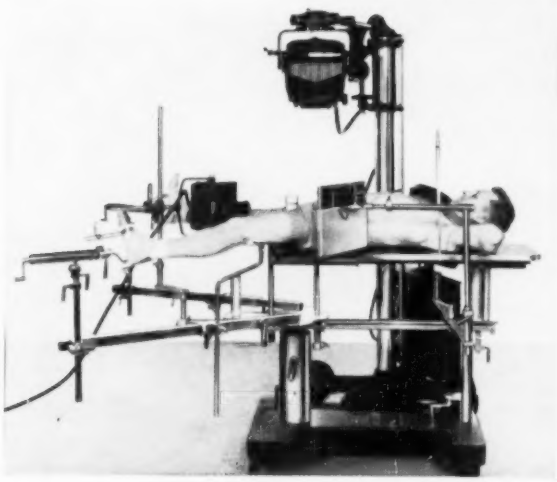

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FIG. 2

FIG. 1

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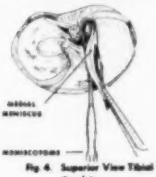

Fig 4. Superior View Tibial Condyles

FIG. 4

If the surgeon favors the intercondylar approach to the posterior horn, the cartilage is freed until it can be dislocated into the notch. The Meniscotome is then slipped over the cartilage in the same manner, pushed back over the posterior horn which is then severed by drawing the knife towards the surgeon.

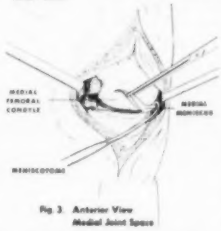

Fig. 3. Anterior View Medial Joint Space

FIG. 3

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Fig 5

FIG. 5

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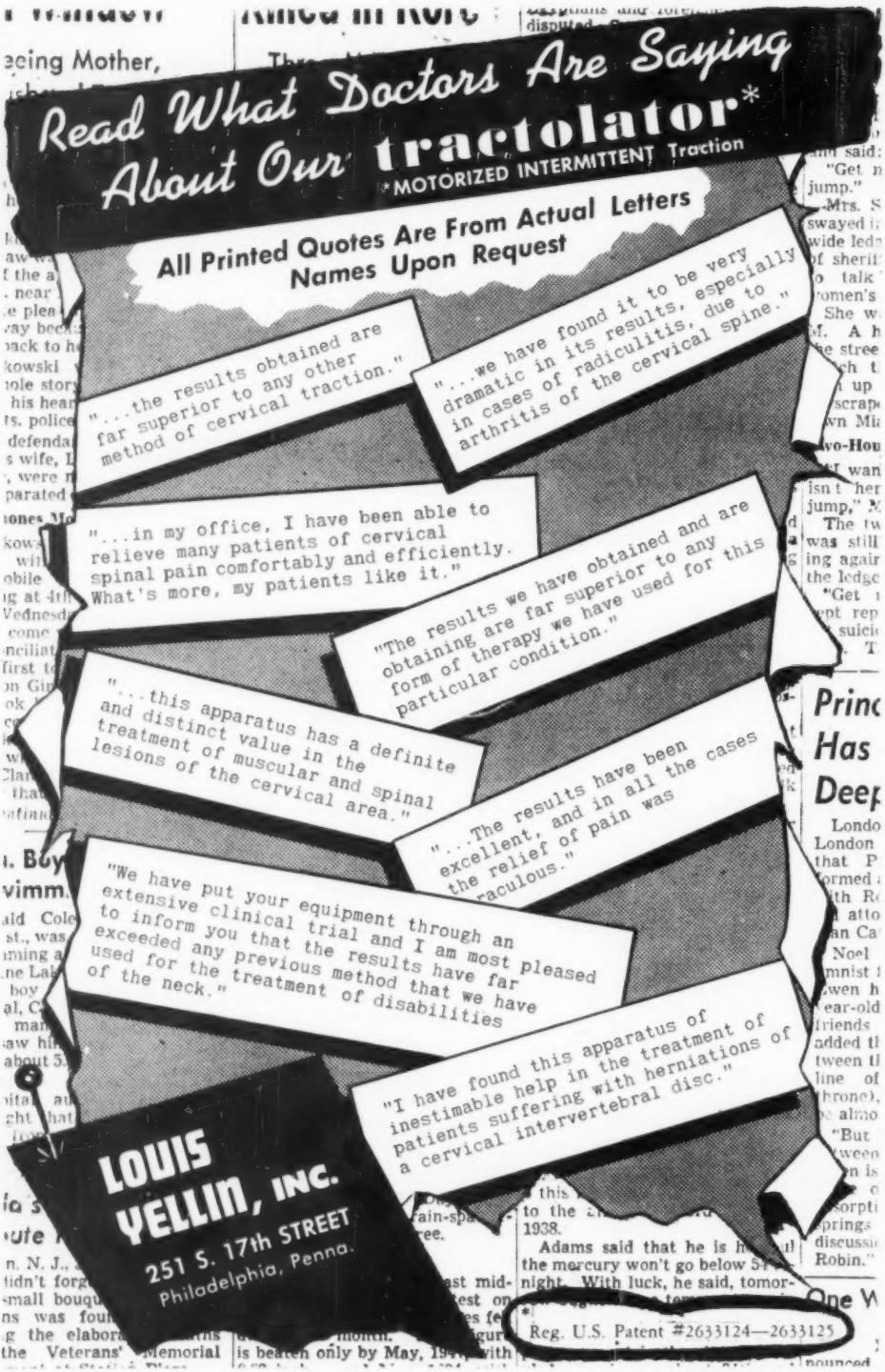
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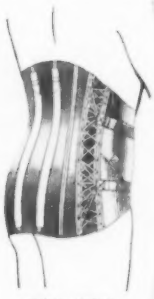

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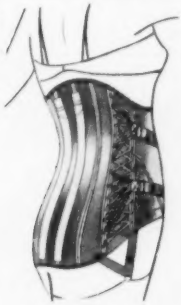

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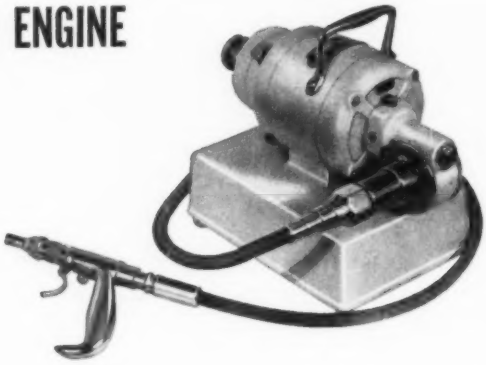

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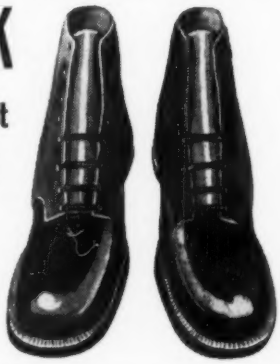

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